

# **A Study of Waste Water Energy Recovery and its Implementation in the Commonwealth of Massachusetts**

A project by:

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## **Abstract**

The Massachusetts Department of Energy Resources is evaluating waste water energy recovery as a potential source of renewable energy. The purpose of this project is to enable the DOER to implement WWER technology in Massachusetts. We interviewed representatives that either had experience with WWER or could benefit from its installation. We developed criteria for the evaluation of potential installation sites. We also devised a process for the selection, installation, and operation of a WWER system at a site in Massachusetts.

## **Executive Summary**

Fossil fuels are the most utilized source of fuel energy. They are abundant and highly energy dense, making them a desirable source of energy. However, they are also responsible for many of our greatest environmental problems. The burning of fossil fuels for energy produces carbon dioxide, nitrous oxide, methane, and other greenhouse gases (GHGs). GHGs released into the atmosphere prevent terrestrial heat from radiating away from the planet. Over time, this results in an increase in the planet's average global temperature. The amount of GHGs in the atmosphere has been steadily increasing for the past 150 years, and almost all of this increase is the result of human activity.

The Commonwealth of Massachusetts has been proactive in implementing programs designed to decrease the Commonwealth's use of fossil fuels by increasing their use of renewable and alternative energy sources. The Renewable Portfolio Standard (RPS), enacted in 2003, and the Alternative Portfolio Standard, enacted in 2009, are examples. The Commonwealth also enacted the Green Communities Act in 2008. As part of the Commonwealth's efforts to implement renewable and alternative technologies, the Massachusetts Department of Energy Resources (DOER) is assessing the possibility of using waste water energy recovery (WWER) to supplement the Commonwealth's heating and cooling needs. The goal of this project is to aid the DOER in their assessment and implementation of WWER technology for heating and cooling needs within Massachusetts.

### **What is Waste Water Energy Recovery?**

WWER is the process by which heat energy is transferred from or to waste water for heating or cooling applications respectively. WWER technology works by adapting the technology that is already used by sewer systems for use in energy recovery applications. There are several components of WWER that function together in order to accomplish the transfer of energy from waste water to their application.. The four main components of a WWER system are the sewage source, the solid liquid separation mechanism, the heat exchanger, and the heat pump.

A study conducted in 2012 in New York City concluded that if 5° F of heat were removed from waste water flowing through the sewer pipes beneath the streets over the course of 1 year, \$90,000,000 worth of energy could be recovered. This statement only reinforces the notion that WWER needs further study, development and implementation. The DOER believes that significant recovery of energy from waste water could result in a substantial reduction in the Commonwealth's consumption of fossil fuel-derived energy.

### **Project Objectives**

To accomplish our goal of aiding the DOER in their assessment and implementation of waste water energy recovery technology within Massachusetts, we completed the following objectives:

1. Develop a list of criteria for the selection of sites with high potential for successful installation of WWER technology.
2. Suggest a process by which a pilot WWER system can be installed in Massachusetts to the DOER.

- Identify strategies for the future implementation of WWER technology throughout Massachusetts.

To accomplish these objectives we:

- Interviewed vendors and representatives of previous installation sites.
- Interviewed sewer company representatives.
- Extensively reviewed case studies and previous implementations.

The following is a list of the vendors, sites, and waste water managers we interviewed:

- International Waste Water Systems (1)
- HUBER (3)
- NovaThermal (1)
- Hidden Fuels (1)
- Correspondence with Philadelphia (1)
- Kent County (1)
- MWRA (4)

## Criteria for the selection of sites with high potential for successful installation of WWER technology

To meet our first objective we developed site selection criteria. We then determined the ideal case for each criterion and prioritized the criteria from most to least important. These criteria, their ideal case, and their priority are listed in Table E.1 below.

**Table E.1: Site Selection Criteria**

Criteria	Ideal Case	Priority
Access to sewage source	Sewage source close to application and surface	1st- make or break due to technical limitations
Status of existing HVAC system	New construction or total system replacement	1st- make or break due to financial limitations
Heating and cooling load	Constant year round demand	3rd- highly desirable for financial reasons
Sewage flow rate	High when compared to energy need	4th- highly desirable for technical reasons
Sewage access point	Wet well or lift station	5th- highly desirable but not required
External funding	Grants or tax rebates available	6th- not required but greatly reduces cost
Energy source replaced or supplemented	High cost energy source such as electric heating	7th- not required but greatly reduces cost
Electricity cost	Low cost per kWh	8th- not required but reduces operating cost
Sewage temperature	Consistently in operating range of heat exchanger	8th- not required but increases efficiency which reduces cost
Monitoring System at or Near the Site	Sewage data available prior to installation	10th- not required but reduces the cost of scoping project

**Criterion 1:** The site must be in close proximity to a sewage source.

Before installing a WWER system, the site's ability to access to a sewage source must be evaluated. Ideally, the sewage access point should be within two city blocks of the site. The sewage source must also be at a depth from the street level that is accessible for installation and maintenance. This criterion is of highest priority because if it is not met, then the installation of a WWER system would not be worthwhile.

**Criterion 2:** The site must be a new construction or have an HVAC system that is due for replacement.

Before installing a WWER system, the HVAC system at the site must be evaluated. The ideal case for this criterion is that the site is a new construction or has an HVAC system that is due for replacement. For new construction and HVAC system replacement, building owners will be incurring some cost for the installation of an HVAC system regardless of the type of system they are installing. Consequently, installing a WWER system will not be a large financial burden on the building owner under these circumstances. However, if the site already has an HVAC system that is not due for replacement and the site owner has no reason to invest in an HVAC system, then the cost of installing the WWER system becomes a significant expense for the site owner. This criterion is of highest priority because if it is not met, the site owner will incur substantial expenses and the installation will not be financially feasible.

The yellow block in Table E.1 contains high to moderate priority criteria that should be met in order to install the WWER system but meeting them is not absolutely necessary for installation. Failing to meet these criteria will cause substantial financial or technical problems for the installation site.

**Criterion 3:** The site should have a year-round heating and cooling load.

Before installing a WWER system, the heating and cooling load at the site must be evaluated. Ideally, the heating and cooling load should be year-round. WWER systems function more efficiently when they are used for cooling applications. However, the system can be used for heating, cooling, or both, depending on the season, as long as the system is being used frequently. A constant heating and cooling load improves the financial viability of a WWER system. This criterion is of high priority because if there is no full time heating or cooling load, then the payback period will be substantially longer, potentially resulting in the scenario where the payback period is longer than the lifetime of the system.

**Criterion 4:** The site must have access to a high flow rate of sewage.

Before installing a WWER system, the flow rate of available sewage must be evaluated. The flow rate a site requires will vary greatly depending on the site. The ideal case for this criterion is that the sewage flow rate is greater than or equal to the flow rate required to meet the heating or cooling load of the site. The flow rate of sewage at a single location varies over time, and this must be accounted for when evaluating the potential for the sewage source to serve as an energy source for the site. This criterion is of moderate priority because failing to meet the site's flow rate requirement results in the need for a backup or supplementary heat source, increasing the payback period of the system.

**Criterion 5:** The site should access the sewage from a wet well or lift station.

Before a WWER system is installed, the access point to the sewage used at the site must be evaluated. Ideally, a site would access sewage at a wet well lift station. Although there are other

options for sewage access, wet well lift stations provide the sewage access needed for installation and maintenance of a WWER system in a way that is both simple and safe. Wet well lift stations tend to be common in sewer systems. If an existing wet well can be utilized, the WWER system would not need to construct an access point, thus saving on installation costs. This criterion is of moderate priority because other access options exist but they are more expensive or make access more difficult.

The green block in Table E.1 contains low priority criteria that are beneficial to meet but are not required for installation. Failing to meet these criteria will increase the payback period for the installation of the WWER system.

**Criterion 6:** Owners of a site should obtain external funding and subsidies.

Before installing a WWER system, the availability of external funding provided for the site must be evaluated. The ideal case for this criterion is that a significant portion of the expenses related to the installation of the system are covered by grants or other sources of external funding. When the owner is responsible for a smaller portion of the financial load, the payback period becomes shorter. This criterion is of low priority because it is beneficial to meet but failing to meet it does not prevent the installation of the WWER system. If this criterion cannot be met, then the payback period will be increased.

**Criterion 7:** The site should use the WWER system to replace or supplement a high cost energy source.

Before a WWER system is installed, the energy source the system replaces or supplements must be evaluated. Ideally, the WWER system should replace or supplement a high cost energy source such as heating oil. This case is ideal because WWER systems reach their payback period by saving their owner money over time. The greater difference between the cost of the original energy source and the cost of using WWER, the shorter the payback period of the system. This criterion is of low priority because it is beneficial to meet but failing to meet it does not prevent the installation of the WWER system. If this criterion is not met, then the payback period of the system will be increased.

**Criterion 8:** The local cost of electricity at the site should be low.

Before installing a WWER system, the cost of electricity at the site needs to be evaluated. Ideally, the electricity cost should be low. The WWER system uses electricity to run some of its components, including the solid liquid separation mechanism, pumps, and heat pump. Consequently, the electricity cost must be reasonably low in order to reduce the operating cost of the system. Electricity costs vary by location and time of day and must be evaluated on a case by case basis. The higher the electricity rate, the longer it takes to reach the payback period. This criterion is of low priority because it is beneficial to meet but failing to meet it does not prevent the installation of the WWER system. If this criterion is not met, then the payback period of the system will be increased. In Massachusetts electricity rates are comparatively high, which could

be a barrier to implementation of WWER systems in the Commonwealth (Energy Information Administration, 2013).

**Criterion 9:** The temperature of the sewage must meet the temperature required for the application and be within the operating range of the heat exchanger.

Before installing a WWER system, the temperature of the sewage available at the site must be evaluated. The ideal case for this criterion is that the temperature of the sewage is either high or low enough for the application and within the optimal range for the heat exchanger. The temperature of the sewage must be as high as possible for a heating application and as low as possible for a cooling application because the closer the temperature of the sewage is to the desired outlet temperature, the less electricity the system will need to use and the lower the operation costs will be. However, the temperature cannot be too high or low because it must also be within the operating range of the heat exchanger or the system will not operate efficiently. This criterion is of low priority because it is beneficial to meet but failing to meet it does not prevent the installation of the WWER system. If this criterion cannot be met, then the operational costs of the system will increase and the payback period of the system will be increased as a result.

**Criterion 10:** The site should be in a location where the sewage system has monitoring equipment installed.

Before installing a WWER system, monitoring systems at or near the site need to be evaluated. Ideally, monitoring systems will have been installed and collected data prior to installation at the site. If there is no available data before the system is installed, in order to conduct a scoping project, data must be collected and monitoring systems must be installed before installation can begin, adding to the cost of the installation.

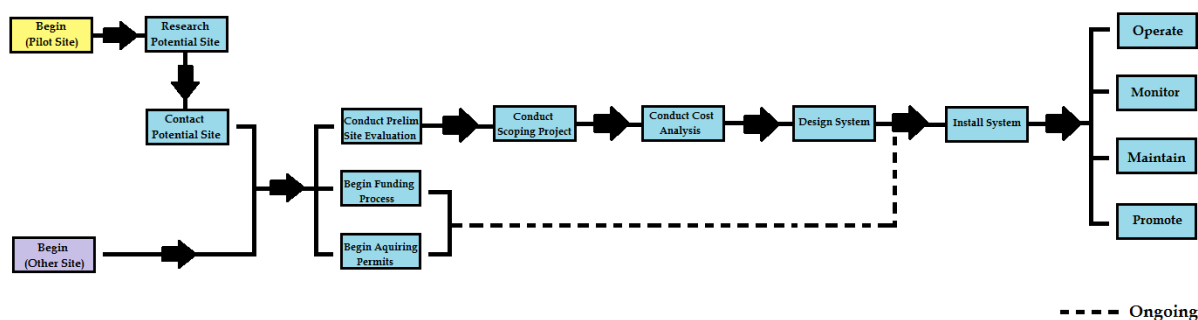
If the monitoring system does not exist before the project to install a WWER system begins, then these monitoring systems will have to be installed, again adding to the cost of the system. This criterion is of low priority because it is beneficial to meet but failing to meet it does not prevent the installation of the WWER system. If this criterion cannot be met, then the installation cost of the system will increase and the payback period of the system will be increased as a result.

## **Recommendations for the Selection and Installation of a Waste Water Energy Recovery Pilot Site**

Installing a pilot site within Massachusetts is an integral part of promoting WWER throughout the Commonwealth. One of the benefits of installing WWER at a pilot site within Massachusetts is that the site can be used to educate potential users of the technology about WWER and encourage the public to install the technology in other locations. Another benefit of installing WWER at a pilot site is that by installing and maintaining the system, the DOER can confirm the viability of the technology and modify regulatory policies to facilitate its implementation and funding. In this section, we discuss the steps that should be taken by the DOER in order to install a WWER system in a pilot site.

**Recommendation 1:** Use the process presented below for the selection and installation of a pilot site.

We have developed a process that the DOER should follow in order to install a WWER system in a pilot site within Massachusetts. We recommend that the DOER follow this process when selecting and installing a pilot site. The pilot site installation process is outlined in a flowchart in Figure E.1. Figure E.1 also shows the installation process for sites that will install WWER systems after the installation of the pilot site. This process will be discussed in Recommendation 11.



**Figure E.1: Pilot Site Installation Process**

## Recommendations for the Promotion of Waste Water Energy Recovery in Massachusetts

Once a successful pilot site has installed a WWER system, the DOER can proceed to promote the use of this technology throughout the Commonwealth. The pilot site can be used to educate potential users of the technology about WWER and encourage the public to install the technology in other locations. The DOER can also use the pilot site to confirm the viability of the technology and modify regulatory policies to facilitate its implementation and funding. In this section we discuss our recommendations for further actions the DOER should take in order to propagate WWER technology throughout Massachusetts. We discuss recommendations that relate to education, funding and regulation, and installation of the technology in the future.

## Recommendations Related to Education

In this section, we discuss several ways of using the pilot site for educational purposes after it has been successfully installed. The educational programs we discuss have two target audiences. The first is the key stakeholders that could be involved in the installation of WWER technology. These stakeholders include building owners, sewer company representatives, company managers, and municipal directors. Stakeholders should be informed about WWER technology so they are aware of the possibility of installing WWER systems and are willing to implement this technology. The second target audience is the general public. The general public should be made aware of WWER technology so knowledge about the technology can spread more easily than it would if only key stakeholders were informed. Directly informing the general public about WWER also gives the advocates of the technology the ability to dispel any myths about the technology and ensure that the public has access to the most accurate information about WWER.



**Recommendation 2:** Open pilot site for educational purposes.

To promote WWER in the Commonwealth, the installed pilot site should be open to the public for viewing and offer tours. Renewable thermal technologies, such as WWER, are not well known by policy makers, the building industry, or the public. At these viewings and tours, the public would be able to see the technology in action, gain knowledge of how WWER works, become aware of the benefits of WWER, and have the opportunity to ask any questions they have and voice their concerns. Having a pilot system installed in Massachusetts would enable Massachusetts policy makers, building owners, and the public to gain the understanding that this technology is locally accessible and is something they could install as well.

As heating and cooling are not tangible, one approach that might be beneficial to the goal of educating the public is the installation of a snow melt system. A town in Colorado is pursuing the idea of using heat recovered from waste water to melt snow on the surfaces as a part of the redevelopment plan. While this specific application was considered for its environmental benefits, applying a snow melt application at or near a WWER pilot site in the Commonwealth would allow for the public to easily see the potential WWER systems have for heating applications.

**Recommendation 3:** Facilitate media attention and advertisement for the pilot site.

Once the pilot site is installed and operational, media should be on site covering events to promote WWER. Inviting different media outlets will broaden the viewing platform for this installation and will make WWER better known. Ideally this media coverage will spark communities' interest in learning about WWER systems.

**Recommendation 4:** Supply communities within Massachusetts with information on WWER.

The DOER should provide informational pamphlets on WWER technology to municipalities throughout Massachusetts. Additionally, at events located at the pilot site, informational brochures and pamphlets that we have created should be distributed. The informational material should include a general overview of the technology, specific benefits, potential costs, and a plan of action to follow if considering implementing WWER. These items should be given to municipal representatives to share with the community at local events such as town meetings. These resources should also include contact information for parties seeking additional information about WWER.

**Recommendation 5:** Hold a webinar for community representatives and other stakeholders within Massachusetts that are interested in WWER.

Holding a webinar is a way to open up communication across the many stakeholders involved in the process of installing WWER. If a municipality is seriously considering WWER, representatives from several different departments and organizations should participate in the webinar. We are providing a slide presentation that should be utilized during the webinar as a

general overview of WWER systems and act as a discussion guide between those in attendance. The webinar will be a way of networking between the potential stakeholders, and another opportunity to ask questions and raise concerns among the stakeholders.

**Recommendation 6:** Hold a summit of current owners and vendors of WWER technology.

There are several different organizations around the world that are independently working to implement WWER technology. Holding a summit would allow for open communication between these organizations. This would be an opportunity for the DOER and any other interested parties in Massachusetts to learn from the experience of other organizations that have worked with this technology. It would also be an opportunity for the DOER to share their experience with WWER and further promote its development. Organizations would also be able to collaborate on problems they are facing and how they have been addressed in the past.

## **Recommendations Related to Funding and Regulation**

**Recommendation 7:** Modify regulatory policy to include WWER technology as an eligible technology for funding by the APS.

Massachusetts should consider WWER and other renewable thermal energy sources as a technology eligible for the APS. This would enable a revenue stream from generation of AECs. Inclusion of renewable thermal sources in the APS will require legislative action. The DOER should continue to promote this idea. In many cases current regulatory policy limits funding to systems that replace certain fossil fuel sources. This policy should be modified to accommodate the installation of WWER technology in sites that are replacing propane, electric heating, and fuel oil.

**Recommendation 8:** Evaluate financial models for available for WWER systems.

There are two financial models available for WWER systems: private ownership, and third-party ownership. The DOER should assess each of these models in the context of financing WWER installations. Based on the current knowledge of these financial models, we believe that the private ownership model will be more beneficial for WWER systems servicing individual sites and the third party model will be more beneficial for WWER systems used for district heating. This assessment should be evaluated and expanded on as the DOER conducts further research. As the DOER continues to evaluate these financial models they should also identify a process for determining which of the two models should be used for any given site.

**Recommendation 9:** Facilitate communication between the parties involved in the installation of WWER systems.

A major difficulty in installing WWER technology is connecting the different organizations and stakeholders that are involved with the installation such as local sewer providers, site owners, engineering consultants, and investors, and enabling them to work together. As a state agency, the DOER is in a position to facilitate collaboration between the parties involved in the installation

process. If a site representative approaches the DOER with the intention of installing a WWER system, the DOER should make efforts to connect that representative with the agencies they will need to contact. The DOER should also ensure that all of the stakeholders and agencies involved in the installation process are communicating as early in the process as possible.

## **Recommendations Related to Future Site Installation**

**Recommendation 10:** Encourage sites to initiate the installation of their own WWER systems.

After the pilot site has been operating, the data collected from the pilot site can be used to promote WWER to other sites. By showing other sites that a pilot WWER system preforms successfully, the DOER can encourage other sites to follow a similar plan of action to install a system of their own. At this point, the DOER is approaching sites to participate in a pilot program. Once this technology is more established in the Commonwealth, sites should be expected to initiate the installation process on their own and seek out support from the DOER. The DOER should then be prepared to provide this support by directing the site as they apply for funding and by facilitating communication between the parties involved in the installation process, as discussed in Recommendations 15 and 16.

**Recommendation 11:** Provide steps for interested sites to follow in order to install WWER systems.

To install WWER systems in the future at locations other than the DOER's pilot site, information should be available regarding the implementation process. The process of implementation for future locations mimics that of the pilot site implementation. The only difference between the two is the steps prior to site evaluation. In a pilot site implementation, the DOER researches and approaches sites that appear to fit some major criteria through basic evaluation with the primary goal of the site being evaluation and education. In the future, the hope is that sites, due to the information and education available as a result of the pilot site, will choose WWER without being approached by the DOER. Please refer to Figure E.1 above for the step by step process of implementation. Just as in a pilot site, future sites should conduct site evaluations using the criteria, involve key stakeholders from the start of the project, conduct a scoping project, conduct cost analysis, design and system, and after installation, operate, monitor, maintain, and promote the WWER system.

## **Conclusion**

Through the completion of this project, we met our objectives of creating a list of criteria that can be used to evaluate potential WWER installation sites, suggesting a process by which a pilot WWER system can be installed in Massachusetts, and identifying strategies for the future implementation of WWER. By completing these objectives, we have added to the available knowledge of WWER. We have also enabled the DOER to proceed with the completion of their goal of increasing the availability of WWER technology throughout the Commonwealth of Massachusetts. As the DOER uses the products of this project to install and promote WWER technology throughout Massachusetts, the Commonwealth will be gaining an additional source of alternative energy. The resulting increase in the use of WWER technology and alternative and renewable energy in Massachusetts as a whole will further contribute to the progress being made in the Commonwealth toward a sustainable future.

## **Acknowledgments**

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# 1.0 Introduction

Fossil fuels are the most utilized source of fuel energy. They are abundant and highly energy dense, making them a desirable source of energy (Alternative Energy, 2013). However, they are also responsible for many of our greatest environmental problems. These problems include global warming, air quality deterioration, oil spills, and acid rain. Nitrogen oxides, products of fossil fuel combustion, contribute to the formation of smog that can irritate the lungs, especially those of people that have asthma, cause bronchitis and pneumonia, and decrease resistance to respiratory infections. Production, transportation, and use of oil can cause water pollution. Oil spills, for example, leave waterways and their surrounding shores polluted for some time and often result in the loss of plant and animal life. Coal mining, especially strip mining, also contributes to water pollution. Coal contains pyrite, a sulfur compound. As water washes through mines, this compound forms a dilute acid, which is then washed into nearby rivers and streams, upsetting the balance of the ecosystem (Union of Concerned Scientists, 2002). The burning of fossil fuels for energy also produces carbon dioxide, nitrous oxide, methane, and other greenhouse gases (GHGs). GHGs released into the atmosphere prevent terrestrial heat from radiating away from the planet. Over time, this results in an increase in the planet's average global temperature. The amount of GHGs in the atmosphere has been steadily increasing for the past 150 years, and almost all of this increase is the result of human activity (EPA, 2013c).

Because of these problems many scientists and government officials have recognized a need for the reduction of fossil fuel use. One strategy to meet this need entails the reduction of overall energy consumption. Energy consumption can be reduced by educating the public about energy consumption and by making changes to everyday routines in order to consciously reduce energy consumption, such as limiting driving and turning off lights when not in use. Energy consumption can also be reduced by developing and encouraging the use of energy efficient technologies, such as fuel efficient engines or energy efficient light bulbs. Another strategy to reduce fossil fuel consumption entails a turn to renewable and alternative energy sources as an alternative to fossil fuels. These two strategies are most effective when used in combination to yield an even greater reduction in fossil fuel use.

Renewable and alternative energy sources provide a method of energy generation that does not rely on fossil fuels. Photovoltaic solar panels, wind turbines, and hydroelectric generators are examples of renewable technologies that produce electricity and are currently being developed and marketed, resulting in an increase of their use (Department of Energy Resources, 2012). Another way in which fossil fuels can be replaced is by using renewable or alternative sources to produce heat energy that would have otherwise been derived from fuel oil or natural gas. Geothermal technology is an example of a renewable thermal technology that harnesses the heat stored below the planet's surface. Another source of heat energy that is not directly reliant on fossil fuel consumption is the heat present in sewage and waste water. This thermal energy can be captured using waste water energy recovery (WWER). The heat energy is transferred from the waste water into clean water, which can in turn be used in heating applications. WWER technology can also be adapted for use in cooling applications.

Massachusetts has been proactive in implementing programs designed to decrease the Commonwealth's use of fossil fuels by increasing their use of renewable and alternative energy sources. For example, in 2003 the Commonwealth enacted the Renewable Portfolio Standard (RPS) to encourage the implementation of renewable technology and require utilities to procure electricity generated from renewable energy sources. In 2009 the Commonwealth enacted an analogous program, the Alternative



Portfolio Standard, to encourage the use of other alternative energy sources (Energy and Environmental Affairs, 2013). The Commonwealth also enacted the Green Communities Act in 2008, which encourages utilities and building owners to increase their energy efficiency and use of renewable and alternative technologies (Conservation Law Foundation, 2013). As part of the Commonwealth's efforts for to implement renewable and alternative technologies, the Massachusetts Department of Energy Resources (DOER) is assessing the possibility of using WWER to supplement the Commonwealth's heating and cooling needs. The DOER believes that significant recovery of energy from waste water could result in a substantial reduction in the Commonwealth's consumption of fossil fuel-derived energy (Department of Energy Resources, 2012). A study conducted in 2012 in New York City concluded that if 5°F of heat were removed from waste water flowing through the sewer pipes beneath the streets over the course of 1 year, \$90,000,000 worth of energy could be recovered (C. Hubbard, personal communication, October 2, 2013). However, before this technology can be implemented in Massachusetts, the DOER needs more information about how this new technology works and operates and a strategy for installing it in viable sites throughout the Commonwealth.

The purpose of this project is to aid the DOER in their assessment and implementation of waste water energy recovery technology within Massachusetts. To accomplish this goal, we completed three objectives. Our first objective was to develop a list of criteria for the selection of sites with high potential for successful installation of WWER technology. Our second objective was to suggest to the DOER a process by which a pilot WWER system can be installed in Massachusetts. Our third objective was to identify strategies for the future implementation of WWER technology throughout Massachusetts. We accomplished these objectives by interviewing vendors and representatives of previous installation sites in order to collect information on the technology for the DOER and begin developing a list of site selection criteria. We then interviewed sewer company representatives and researched potential sites in Massachusetts that could potentially benefit from WWER technology in order to collect additional information, further refine our site selection criteria, and provide recommendations for a pilot program.

As a result of our research we created several products. First, we developed a list of criteria for evaluating sites as potential WWER installations. We were able to justify each criterion we identified, assess its importance, and identify the consequence of failing to meet it. For example, we found that buildings that have a large annual demand for heating or cooling are more likely to be cost effective sites for WWER. If this criterion is not met at a site then the WWER system will not be operational year-round, resulting in a longer payback period. Second, we were able to use the criteria to evaluate a number of sites that the DOER should pursue as potential pilot sites. Third, we recommended a strategy that the DOER should follow to successfully implement WWER technology in the future. This strategy included using the criteria our team created to choose a site, following our strategy for implementation, and taking steps toward the promotion of WWER by educating, adjusting regulations, and encouraging other sites to pursue the installation of WWER.

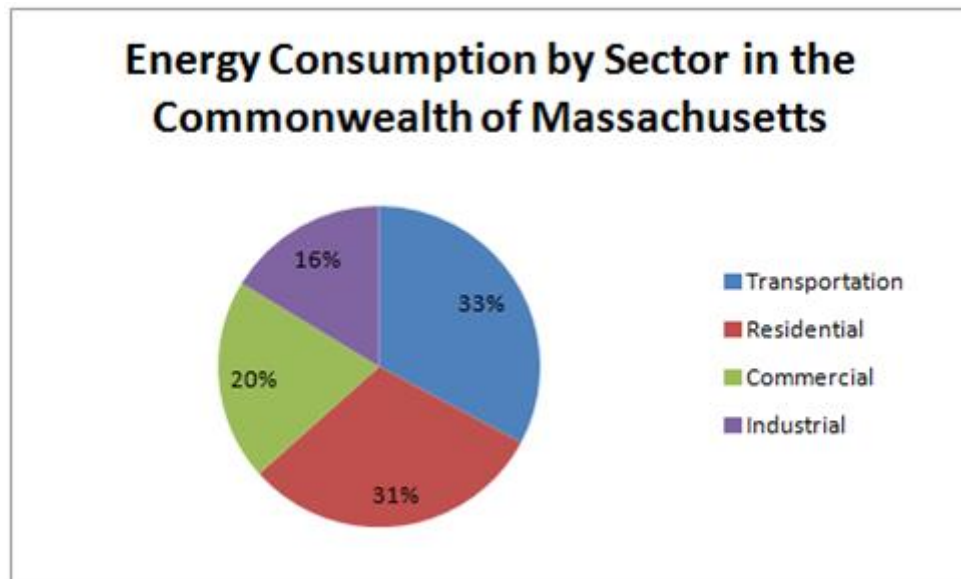
Through this project, we hope to increase the availability of knowledge regarding WWER, and further promote its implementation and development throughout the Commonwealth of Massachusetts. Through the use of such an overlooked energy source flowing under our city streets, waste water, we hope to further the pursuit for sustainability. While this project focused on the needs of the DOER, the project's results and the subsequent work done by the DOER can serve as a model for other municipalities, state agencies, and private investors to follow when pursuing the implementation of this technology.

## 2.0 Background

In this chapter, we begin with a discussion of the need for waste water energy recovery (WWER) in Massachusetts and its potential role in the Commonwealth. This discussion includes a description of the current fuel sources and energy consumption in Massachusetts and a description of the Commonwealth's policies to encourage the use of renewable and alternative energy sources. Next, we describe the rationale for promoting WWER, the general set up of a complete system, and the technology involved in WWER systems in detail. Finally, we discuss the different ways in which WWER technology can be implemented for different applications.

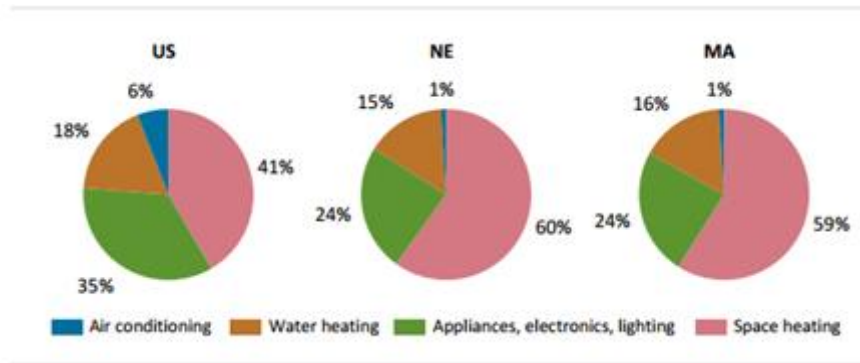
### 2.1 Current Fuel Sources and Energy Consumption in Massachusetts

In Massachusetts, the transportation sector consumed the biggest portion of total energy consumed with 458,464 billion BTU (33 %). A British Thermal Unit (BTU) is a measure of energy equivalent to the amount of heat required to raise the temperature of 1 pound of liquid water by 1 °F (Silverman, n.d.). The residential sector followed close behind, consuming 426,949 billion BTU (31 %). The commercial and industrial sectors consumed about half of that amount, consuming 283,577 billion BTU (20 %) and 227,872 billion BTU (16 %) respectively (Department of Energy Resources, 2012). This information is represented visually in Figure 2.1.



**Figure 2.1: Energy Consumption by Sector in the Commonwealth of Massachusetts (Department of Energy Resources, 2011)**

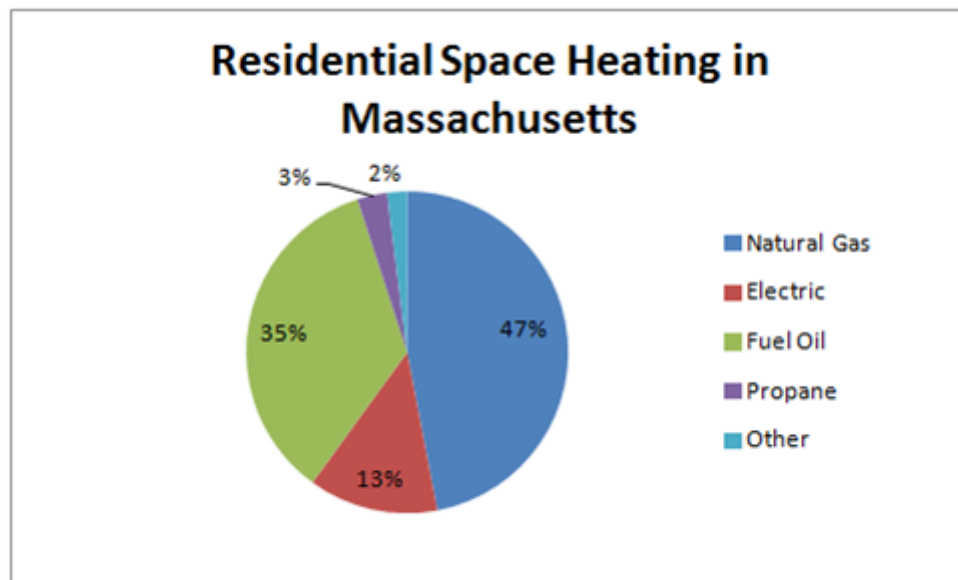
Because the weather in Massachusetts and New England is cooler than other areas of the United States, space heating makes up a greater portion of energy use in homes (59%) compared to the U.S. average, as shown in Figure 2.2, and air conditioning makes up only 1% of energy use (Environmental Information Administration, 2009).



**Figure 2.2: Energy End Use**

**(Environmental Information Administration, 2009)**

The energy consumed in Massachusetts is derived mostly from fossil fuels. Using residential space heating applications as an example, 85% of the energy used in residential space heating in Massachusetts is directly derived from fossil fuels: 47% from natural gas, 35% from fuel oil, and 3% from propane. In addition, 13% of the energy used in residential space heating in Massachusetts is provided by electricity, which is derived mostly from fossil fuels. The remaining 2% of the energy used in residential space heating in Massachusetts is categorized as “other” sources and includes renewable and alternative energy sources (Department of Energy Resources, 2012). These data are represented graphically in Figure 2.3.



**Figure 2.3: Residential Space Heating in Massachusetts**

**(Department of Energy Resources, 2011)**

These energy sources, which are predominantly fossil fuels or fossil fuel derived, produce carbon dioxide and other greenhouse gases (GHG) that contribute to climate change and other environmental

problems in addition to health issues. Reduction of GHG emissions is necessary for a more stable and sustainable environmental future.

## **2.2 Massachusetts Policies to Reduce Fossil Fuel Use**

In an effort to reduce the negative impacts of using fossil fuels in Massachusetts, the Commonwealth has enacted several policies on energy usage and production. Some of these policies provide incentive toward the development and installation of renewable and alternative technologies, while others disincentivize the use of fossil fuels. Regulations regarding renewable and alternative technologies must be considered when installing these types of technologies in Massachusetts in order to avoid any barriers that may be present during installation and take full advantage of any incentives that may be provided.

The Renewable Portfolio Standard (RPS) is a regulatory program that requires that a minimum portion of electricity generated in the Commonwealth be generated by renewable energy sources. The RPS requires that the percent of electricity derived from renewable sources increases by 1% each year, starting in 2009 at 4% (Energy and Environmental Affairs, 2010). The technologies that qualify for the RPS are divided into two classes:

- Class I includes systems that utilize solar, wind, hydropower, geothermal, methane recycled from landfills or anaerobic digesters, or certain biofuels and began operation during or after 1998. The portion of energy produced by Class I systems is required to grow by 1% each year.
- Class II includes renewable systems of the same types of technologies as Class I that began operation before 1998. The portion of energy produced by Class II renewable systems must meet 3.6% of electricity generation. Class II also includes waste energy, meaning energy derived from the burning of waste, which must meet 3.5% of electricity generation.

The Alternative Portfolio Standard (APS) is an additional regulatory program that provides incentive for electricity generation companies to utilize alternative energy resources that do not qualify for the RPS. The APS requires that the percent of electricity derived from eligible alternative technologies starts at 1% in 2009 and increases by 0.5% each year. Technologies eligible for the APS include combined heat and power, flywheel storage, coal gasification, and efficient steam technologies (Energy and Environmental Affairs, 2010).

As part of the RPS, Renewable Energy Certificates (RECs) are available to create a market incentive for producing renewable energy. An REC is credited to a renewable energy supplier for each megawatt hour of electricity they produce (Energy and Environmental Affairs, 2010). RECs are awarded to the supplier in addition to any monetary compensation they receive for selling the electricity. RECs can then be purchased by other electricity providers as a substitute for producing electricity from renewable sources in order to comply with the RPS. In this way, RECs serve as a means for renewable electricity providers to be additionally incentivized and compensated for their contribution to the Commonwealth's renewably derived electricity. If an electricity provider fails to produce enough renewably derived electricity to comply with the RPS, in addition to buying RECs from other electricity providers they can also purchase RECs from the DOER. RECs purchased from the DOER provide funding for government programs to encourage the growth of renewable energy technologies.

An Alternative Energy Certificate (AEC) functions analogously. AECs are awarded to alternative energy producers, and can be purchased by energy providers to meet the requirements of the APS. AECs purchased from the DOER provide funding for government programs to encourage the growth of alternative energy technologies.

These programs are intended to encourage the growth of renewable and alternative technology by providing incentives for companies to seek out this technology and consequently drive the market toward the further development of this technology. Renewable and alternative technology owners can benefit from these programs because they may be eligible for RECs and AECs, which they could then sell to energy providers. RECs and AECs can also be used to fund DOER renewable and alternative technology projects and encourage the growth of this technology (Massachusetts Department of Energy Resources, 2012)

### **2.3 The Role of Waste Water Energy Recovery in Massachusetts under the APS**

Waste water energy recovery (WWER) technology is among the renewable and alternative technologies the MA DOER is considering implementing under the APS program. Currently, WWER is not recognized under the APS as a renewable thermal technology. WWER utilizes an otherwise wasted heat resource. Specifically, the heat contained in waste water from showers, sinks, washing machines, industrial effluent, and other sources is utilized for heating and cooling applications (Energy and Environmental Affairs, 2012). A study conducted in Brainerd, MN concluded that an average of one hundred dollars' worth of heat energy flows under each manhole cover in that city every day (P. Nelson, personal communication, September 19, 2013). A study conducted in 2012 in New York City concluded that if 5°F of heat were removed from waste water flowing through the sewer pipes beneath the streets over the course of 1 year, \$90,000,000 worth of energy could be recovered (C. Hubbard, personal communication, October 2, 2013). Typically, energy-rich waste water is added to sewer systems, treated by a waste water treatment facility, and eventually returns to the environment. WWER technology can be used to recover this heat resource from the sewer system.

The WWER process uses only a small amount of electricity; typical coefficients of performance (COPs) for these systems are 3.0 to 4.0 (Chen, 2011). Because only a small amount of electricity is used by WWER systems, the amount of carbon dioxide generated by using fossil fuels to provide heat is greatly reduced by using these systems. If implemented effectively, the MA DOER believes WWER technology can provide Massachusetts with a useful alternative to fossil fuel based heat energy sources. For this reason, WWER systems are among the technologies in which the Commonwealth is planning to explore and, if successful, promote. However, before these systems can be implemented, the MA DOER needs more information about how they function and where they can be used effectively.

**Coefficient of performance (COP):**  
In either a heat pump or complete WWER system, the ratio of heat energy yielded to the electrical energy consumed

## 2.4 Waste Water Energy Recovery Technology

WWER is the process by which heat energy is transferred from or to waste water for heating or cooling applications respectively. WWER technology works by adapting the technology that is already used by sewer systems for use in energy recovery applications. The technology is repurposed and incorporated into WWER systems designed for specific applications. WWER systems can also be used in cooling applications by adapting the system to transfer heat to the sewage rather than extracting heat from it. In this section, we discuss the general configuration of WWER systems. We then discuss how these systems can be used for different applications. Finally, we will discuss the different types of technology that are used in WWER and how they have been repurposed for WWER systems.

### 2.4.1 Uses of Waste Water Energy Recovery

WWER technology can be used for several different heating and cooling applications, including space heating, water heating, space cooling, water cooling. WWER can be implemented **on-site** or **off-site**. An example of WWER used in a heating application is the former 2010 winter Olympic Village

**on-site-** at the site of the treatment plant  
**off-site-** WWER applications that use the energy at some other location, usually within close proximity to the sewage source

buildings in Vancouver that were converted to apartment buildings and are heated by the effluent from a nearby sewage plant (Godfrey, 2009). WWER technology can also be used to transfer heat to sewage for cooling applications. The Wintower high-rise building at Winterthur, Switzerland utilizes WWER to heat and cool their buildings. The system can be used for cooling because the wastewater acts as a heat sink and can absorb up to 840 kW of heat from the building (HUBER, 2011a).

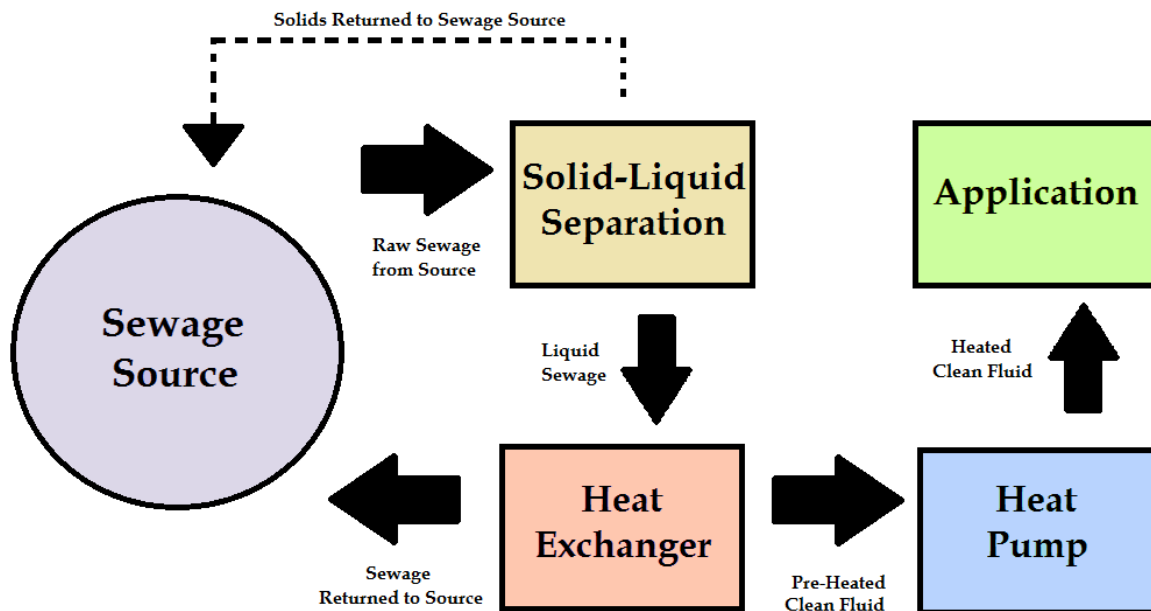
An example of WWER space heating can be found in central buildings in Avon, Colorado, which are heated by the city's waste treatment plant (Vandenburgh, 2011). In contrast, a study in Hong Kong utilized a type of WWER technology to only heat water. Their system utilized a simple, single-pass counter flow heat exchanger that was horizontally installed beneath the shower drain (Wong, 2010). More information regarding this case study can be found in Appendix E.

WWER applications can either be on-site or off-site. On-site WWER applications are defined as WWER applications that use the energy at the site of a waste water treatment plant or lift station facility. Off-site WWER applications are defined as WWER applications that use the energy at some other location, usually within close proximity to the sewage source. For example, the study in Hong Kong considered waste heat recovery from shower drains in high-rise residential buildings (Wong, 2010). This collection location is considered off-site because rather than being at the waste water treatment facility, the application is near the sewage source but not at a treatment facility. Conversely, NovaThermal's installation in Philadelphia's waste water treatment plant which heats an office using the plant effluent is considered an on-site application (Chen, 2011). Typically, on-site systems use plant effluent pipes as their sewage source while off-site systems use raw sewage as their sewage source.

For this project, we will be considering off-site applications of WWER used for space heating or cooling. This is in part because there is less information available on off-site WWER applications. Additionally, implementation off-site allows for a wider range of applications outside of waste water treatment facilities.

## 2.4.2 Waste Water Energy Recovery Systems

This section outlines the general configuration of a WWER system and the different types of components used in WWER systems. Sewer access points, and solid-liquid separation technology, heat exchangers, and heat pumps, are discussed. These components of WWER systems are not new technologies. Heat pumps and heat exchangers, for example, have been used in applications such as air conditioning units, freezers, and other HVAC units for many years. Because the technology used in WWER systems is commonly used in other applications, these systems can be understood and maintained by sewer workers without any additional training despite the fact that this application of the technology is new. The general configuration of a WWER system is represented in Figure 2.4.



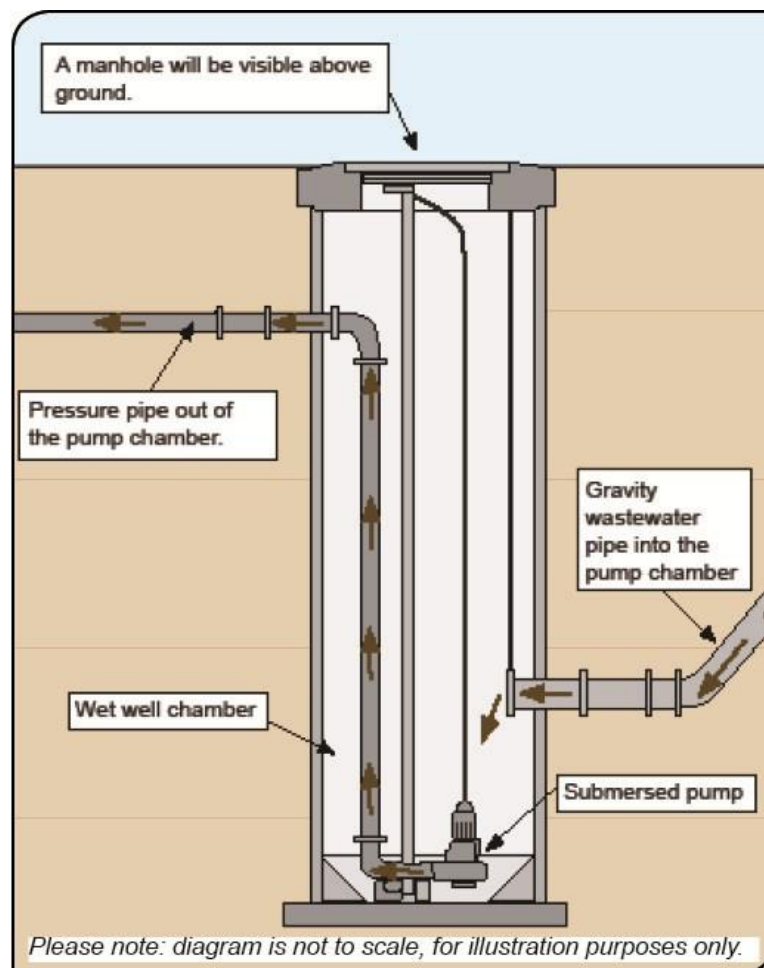
**Figure 2.4: General WWER System Configuration**

**Sewage Source:** To start, the sewage is diverted from its source to a solid liquid separation unit. The present day sewer systems found throughout the country are complex systems of infrastructure that play a vital role in keeping our cities and towns clean and sanitary. In most cases the sewage flows through pipes with no additional assistance other than gravity. However, when the topography prevents gravity from moving the sewage downhill, the sewage must be pumped from the low elevation to the higher elevation. There are special pumps to handle the raw sewage at these stations, which are called lift stations (“Wastewater Treatment”, 2013a).

There are two types of basic lift stations: wet wells with a submerged pump, and wet wells with a pump that is not submerged. In both types of wells there is access to the system normally through a manhole in the street above. In a wet well with a submerged pump, the pump needs to be raised to the surface for maintenance. In a wet well with an unsubmerged pump, access is usually through an adjacent opening to the wet well. In the context of waste water heat recovery these lift stations, especially wet wells, allow an easy access point for the heat recovery technologies to access the sewer flow that contains the potential heat (“Wastewater Treatment”, 2013b).

A wet well installation has only one chamber to receive the sewage flowing downhill with gravity. The sewage is held in the well until it is ready to be pumped out. Each wet well contains one primary pump and one additional pump that operates when the primary pump is removed for repair. In a wet well, the pumps are usually specially designed so that they are submersed in the sewer chamber. An advantage of wet wells in WWER applications is that they are compact. The WWER system can be fit into the wet well to save space. They are also a point at which the sewage can be easily accessed (“Wastewater Treatment”, 2013b). For example, NovaThermal is a small vendor company based in China that is using their technologies in WWER systems (J. Wang, personal communication, September 26, 2013; see Appendix D.2 for more details). NovaThermal’s system collects raw sewage from the city sewer main into a wet well. Another WWER system, Sewage SHARC can be implemented using various sewage sources, but works best when installed in a lift station (G. Sauter, personal communication, September 3, 2013; see Appendix D.1 for more details).

An example of a wet well lift station can be seen below in Figure 2.5



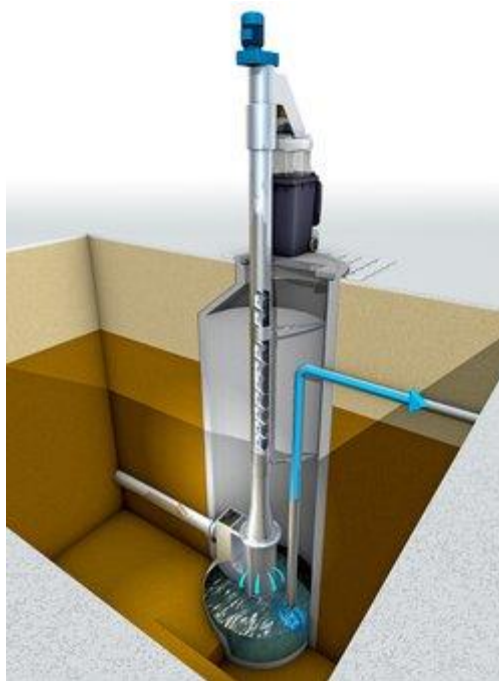
**Figure 2.5: Diagram of an Underground Wastewater Lift Station (SCIRT Rebuilding Infrastructure, 2013)**

**Solid Liquid Separation:** Solids are then separated from the liquid sewage and returned to the sewage source. Raw sewage frequently contains materials that can clog and disrupt flow through heat exchangers



and heat pumps. If the pumps in WWER systems were to become clogged, they would need to undergo a manual, labor intensive, cleaning process. This would cause costly delays that result in a high maintenance cost for the system. To prevent this, solid liquid separation equipment must be used.

Many lift stations have self-cleaning screens to help remove the solid waste from the liquid sewage. This allows for the sewer water to flow more readily through the pumps without clogging, and in turn allows for lower maintenance costs. There are many different versions of these self-cleaning screens. When applied to a WWER system the configuration is usually a vertical screen basket and a shafted auger inside a vertical tube. The wastewater flows through an inflow pipe chamber into the screen basket. Within the screen basket the flights of the screw are equipped with wear-resistant brushes for effective cleaning of the screen. The screened wastewater is pumped to the higher level with ease. Figure 2.6 is an example of a wet well that contains a self-cleaning screen. For example, HUBER, a company that produces machines, plants and stainless steel equipment for municipal and industrial water, wastewater and sludge treatment, extracts sewage from the main sewer line (HUBER, 2011b; see Appendix D.4 for more details). The raw sewage is pumped up to the surface with the ROTAMAT® Pumping Station Screen Rok 4 (HUBER, 2011d). The RoK 4 separates solid and liquid sewage so that the raw sewage does not clog the equipment. The sewage moves through the vertical self-cleaning screen with the help of an auger, and the screenings fall back into the sewage source. (HUBER, 2011d).



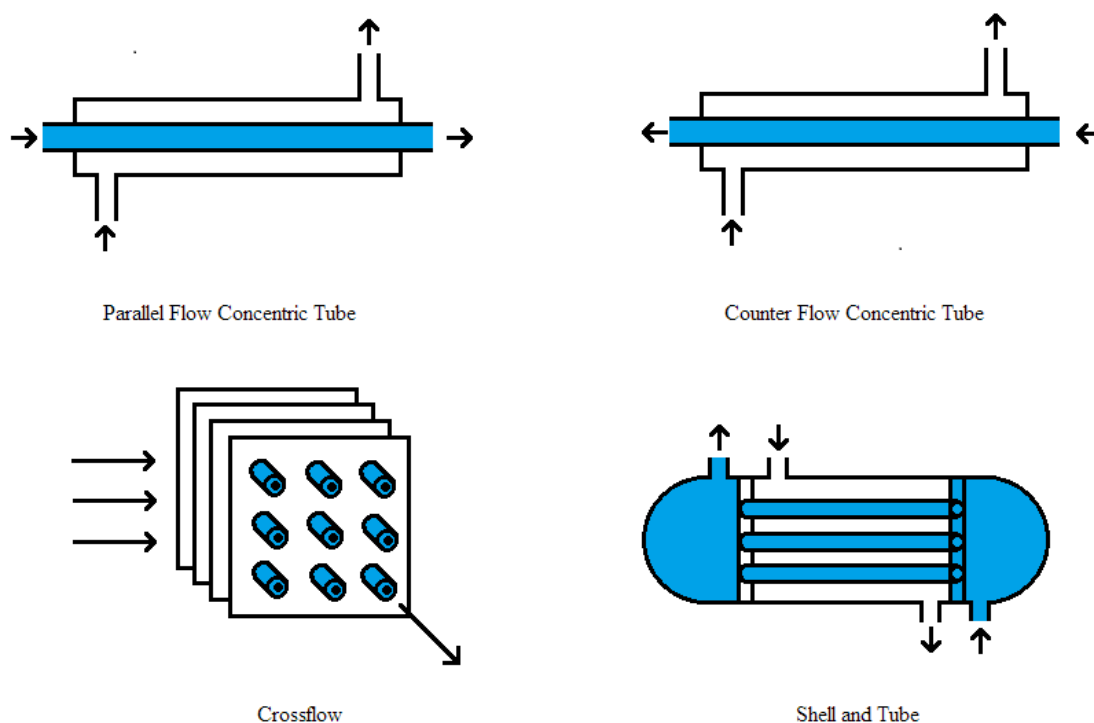
**Figure 2.6: Wet Well with Self Cleaning Screen (HUBER, 2011d)**

Macerators are another method of solid-liquid separation. A potential challenge in the application of WWER in treatment facilities solid objects found in raw sewage. A macerator works similarly to a garbage disposal in a kitchen sink, allowing dissolved sewage solids to freely flow through the heat exchangers and heat pumps. Just as in other solid-liquid separation mechanisms, macerators are placed upstream of heat pumps and heat exchangers to minimize flow obstruction in WWER systems (G. Sauter, personal communication, September 3, 2012) The NovaThermal system sends sewage to a machine that prevents blockages with both screens and grinders (J. Wang, September 26, 2013). The Sewage SHARC

utilizes a macerator, to minimize solid materials within the sewage (G. Sauter, personal communication, September 3, 2013). The solid-liquid separation step is necessary to prevent clogging within the WWER system and ensure that the system works effectively.

**Heat Exchangers:** Next, the liquid sewage is run through the system's heat exchanger and is then returned to the sewage source. Heat exchangers are systems used to transfer heat from one fluid to another. In a heat exchanger, a hot fluid and cold fluid are passed through the exchanger. The heat is then transferred from the hot fluid through the heat exchanger and into the cold fluid. Heat exchangers operate continuously, and the heat exchange process occurs as the fluids pass through the device (Bergman & Incropera, 2011).

There are several types of heat exchangers that may be useful for recovering heat from waste water. These include parallel flow concentric tube heat exchangers, counter flow concentric tube heat exchangers, cross-flow heat exchangers, and shell-and-tube heat exchangers (Bergman & Incropera, 2011). These types of heat exchangers can be seen in Figure 2.7.



**Figure 2.7: Types of Heat Exchangers**

Concentric tube heat exchangers have one fluid flowing through the central pipe and the other fluid flowing through an **annulus**. Parallel flow concentric tube heat exchangers have the two fluids flowing in the same direction while counter flow concentric tube heat exchangers have the two fluids flowing in opposite directions. Cross-flow heat exchangers consist of a group of tubes with one of the fluids flowing through them. The other fluid flows perpendicularly to the tubes in a larger pipe, which all of the cross flow tubes intersect and pass through. Sewage SHARC uses a plate heat exchanger, a type of cross-flow heat exchanger, within their

**annulus**- the outer pipe in a concentric tube heat exchanger

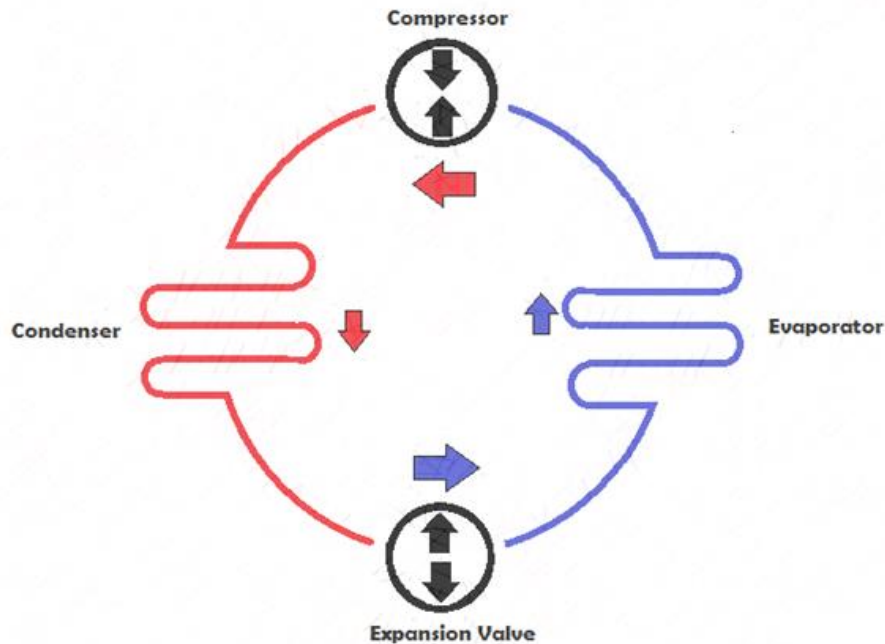
system (G. Sauter, personal communication, September 3, 2013). Shell and tube heat exchangers are made up of a system of tubing that contains one fluid and a shell that houses the tubing and contains the other fluid.

Heat exchangers are useful in WWER applications because the fluids in the heat exchanger never mix. Heat is transferred through the conductive piping, from the waste water to a working fluid, without the fluids ever coming in contact (Bergman & Incropera, 2011). Because the fluids never come in direct contact with one another, it is safe to use waste water to heat the working fluid without the risk of potable water contamination. The role of the heat exchanger in the WWER system is to transfer as much heat as possible given the temperature of the waste water before using heat pumps to further heat the fluid to the desired temperature. The fluid being heated in a heat exchanger will never reach a temperature that exceeds the inlet temperature of the hot fluid. This property of heat exchangers limits the temperature a WWER system can yield using heat exchangers alone. However, heat exchangers do not require a power source to transfer heat naturally from hot to cold. This is why most systems use a heat exchanger in combination with a heat pump in order to reach the desired outlet temperature while using as little energy as possible. Heat exchangers can also be used in cooling applications by transferring heat from warm air or water to cooler waste water. HUBER's heat exchanger, RoWin, also includes a data recording system that keeps records and archives of all relevant process data, such as volume flows and temperatures, so that problems or changes in the process can be located and repaired (HUBER, 2011c).

**Heat Pumps:** Finally, the clean stream from the heat exchanger that the liquid sewage's heat was transferred to is run through a heat pump to further increase the stream's temperature to the desired outlet temperature. Heat pumps are used in WWER systems to extract more energy than can be transferred by heat exchangers alone. Heat pumps are not limited by the physics of transporting heat in the natural flowing direction, from warmer to colder, because they use an external energy source to overcome the temperature gradient. Heat pumps work in the opposite direction, transporting heat from colder fluids to warmer ones.

The basic components of heat pump include an evaporator, a condenser, and expansion valve, and a compressor. The main heating and cooling components of a heat pump are the expansion valve and the compressor. The expansion and contraction of the heated or cooled substance is related to the temperature of the air or water. By controlling the expansion and compression, temperature is controlled. With the intake of energy through the heat exchanger, the heat pump transports that energy to air or water medians (Goldschmidt, 1984).

This process is schematically represented in Figure 2.8.



**Figure 2.8: Heat Pump Diagram**

Most WWER systems use both heat exchangers and heat pumps. The clean stream's temperature is raised as much as possible from the sewage stream within the heat exchanger. Heat pumps are then used to further increase the temperature of the clean stream to the desired outlet temperature. As a final step in the HUBER system for example, the heat collected is utilized for application with the help of heat pumps to reach the desired outlet temperature (HUBER, 2011a). The transportation against the natural direction of heat flow requires an energy source, electricity, to create a **temperature lift** (Goldschmidt, 1984). The temperature lift is defined as the difference between fluid temperatures before and after heat pump circulation. For example, in an air conditioning unit heat is being transferred from the cooler fluid, the air inside of a room or building, to a warmer fluid, the air outside of the building or room, and consequently moving against the natural energy flow using electricity (Goldschmidt, 1984).

**temperature lift-** the difference between fluid temperatures before and after heat pump circulation

Heat pumps are also regularly used in heating applications, specifically, electric heating. When paired with a heat exchanger, the heat naturally flowing across the gradient reduces the temperature the heat pump needs to work from. As heat pumps utilize electricity, the cost of electricity in the implementation location highly influences how cost effective heat pumps are. A high electricity cost will often increase the cost of using a heat pump.

## 2.5 The Information Gaps Preventing the Implementation of Waste Water Energy Recovery in Massachusetts

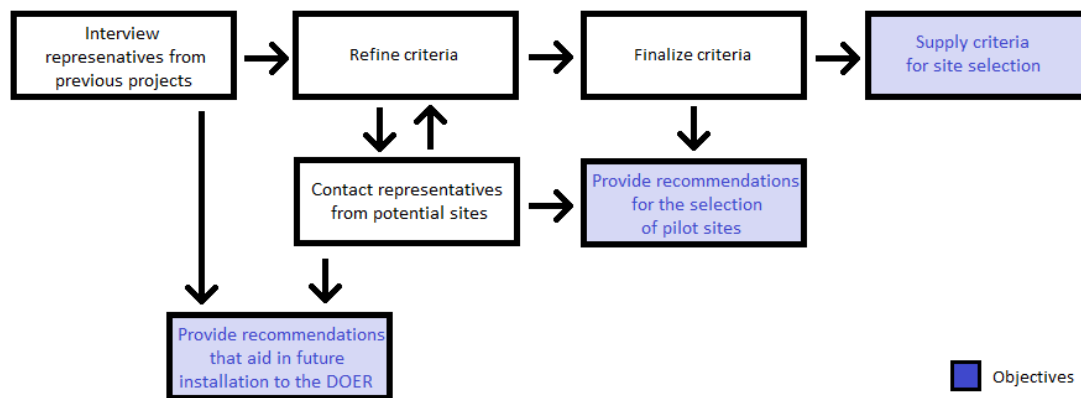
Before WWER technology can be implemented in Massachusetts, more technical, financial, and regulatory information is needed. In North America, there are not many installations of these systems and very little is known about WWER. More research must be conducted on WWER technology and its implementation in other parts of the world that are more familiar with this technology. Even after more information is known about WWER, without a plan for a WWER implementation process in place, progress towards the implementation of WWER will not occur. Implementation is a multifaceted procedure that frequently is not a linear process. The DOER needs to know the process by which WWER technology can be successfully implemented. A method of selecting sites in which this technology can be implemented must also be developed. The DOER must also be aware of any barriers that could be faced during installation and the methods used to overcome them. Knowing the difficulties that could be encountered before embarking on the project allows for proper planning. This project aimed to provide the DOER with the information needed to proceed with the implementation of WWER, provide a method of selecting sites in which WWER can be installed, devise a plan to implement WWER technology while accounting for any barriers the DOER may face throughout the implementation process.

### 3.0 Methodology

The purpose of this project was to aid the DOER in their assessment and implementation of waste water energy recovery (WWER) technology. To accomplish this goal, we organized our project around three objectives:

1. Develop a list of criteria for the selection of high potential installation sites.
2. Suggest a process by which a pilot WWER system can be installed in Massachusetts to the DOER.
3. Identify strategies for the future implementation of WWER technology throughout Massachusetts.

In this chapter, we will discuss in detail the process by which we completed these objectives, illustrated by Figure 3.1.



**Figure 3.1: Task Flow Chart**

We first conducted preliminary research to determine the data we needed to collect and on the companies and sites we wished to contact. We were then able to conduct interviews with WWER technology vendors and representatives from previous installation sites. Next we analyzed the information received from these interviews and used it to prepare to contact sewer company representatives and potential site representatives. We were then able to conduct the interviews with sewer company representatives and contact potential site representatives. After this process was completed we were able to analyze all of the data we had collected and use it to develop a list of criteria, suggest a process for the installation, and identify strategies for future implementations of WWER.

#### 3.1 Identification of Data Needs

We began our data collection process by determining the types of data we would need in order to conduct the analysis necessary for the completion of our objectives. We began by researching studies conducted by the DOER in previous years on renewable and alternative technologies, specifically the 2012 Heating and Cooling in the Massachusetts Alternative Portfolio Standard Report (Massachusetts Department of Energy Resources, 2012) to the Legislature and the Massachusetts Renewable Heating and Cooling Opportunities and Impacts Study (Massachusetts Department of Energy Resources, 2012). The Alternative Portfolio Standard report was the result of research on the state of development of alternative

heating and cooling technologies within Massachusetts. The Opportunities and Impacts Study analyzed the opportunities and possible benefits of increased use of renewable heating and cooling technologies in Massachusetts. These reports suggested the types of data needed for the analysis of existing installation sites and potential WWER installation in Massachusetts. The information we determined we would need to collect in order to conduct this analysis are shown in Table 3.1.

**Table 3.1: Preliminary List of Data to be Collected**

Determining Site Potential	Evaluating Cost Effectiveness	Synthesizing Regulatory Data
What made previous sites successful?	Previous energy consumption and expenses	Building regulations
Barriers for installation in previous sites	Expected energy savings	Sewer regulations
Challenges faced in previous sites after installation	Upfront cost of installation	Workforce regulations
Barriers for installation in potential sites	Cost of determining water temperature and flow rate	EPA regulations/ water quality regulations
Indications that potential site will be expected to face challenges after installation	Cost of maintenance	Tax incentives
Indications that potential site will be successful	Grants and tax rebates available	
	Payback period	

### 3.2 Creation of Vendor and Previous Installation Representative Interview Guides

Once we identified the data needs we were able to formulate a list of questions to ask each of the respondents based on both our data collection research and the research on the specific respondents. These questions were further refined and organized into interview guides. We determined that our respondents could be organized into three groups:

1. Vendors: respondents that we contacted for information on a specific company's WWER system.
2. Representatives of previous installations: the respondents that we contacted for information on-sites that have installed WWER systems.
3. Representatives of waste water treatment facilities (WWTF): the respondents that we contacted for information on the Massachusetts sewage system

We determined that we would be more prepared to interview WWTF representatives and research potential sites after we had the information collected by conducting interviews with previous installation representatives and vendors. We resolved to conduct two separate sets of interviews; first we conducted interviews with previous installation representatives and vendors, then we conducted interviews with sewer company representatives and contacted potential site representatives.

We made separate interview guides for each respondent group. These interview guides were organized by the topics “Technological”, “Financial”, and “Regulatory”. These topics relate to the data needs presented in Table 3.1. Under each topic heading were a number of major questions related to that topic. Follow-up questions were listed under each major question. For example, in the “Technological” section of the vendor interview under the main question “What is involved in the installation process?” we included the follow-up question “Can your system be installed as both an upgrade and a retrofit?” The questions in each interview guide were designed to prompt a discussion that would yield the information we had determined we would need. The interview guides for each group can be found in Appendix B.

### **3.3 Vendor and Previous Installation Representative Interview Process**

Interviews with both previous installation representatives and vendors were designed to elicit information about the WWER technology in use from multiple unique perspectives. This enabled us to limit the effect of any biases vendors could have had and obtain the most reliable information. The vendors that were interviewed were HUBER (3 representatives), NovaThermal (1 representative), and Sewage SHARC (1 representative). Kent County (1 representative), Philadelphia (1 representative, email correspondence), and Hidden Fuels (1 representative) were previous installation sites that we were able to contact and speak with.

We initially contacted potential respondents over the phone, and once the interview date was set, we followed up with a reminder email. Most previous installation representative and vendor interviews were conducted over the phone. One vendor interview was conducted in person as a meeting at the DOER office. At the start of each interview we explained our project to the respondent and informed them that their answers would be kept confidential unless they stated otherwise. All respondents chose to waive confidentiality, but some respondents were unable to answer some of our questions because they were not able to share proprietary information with us. During the interviews, one group member lead the conversation with the contact, while the second and third group members took notes and occasionally contributed additional questions as the interview progressed. These roles rotated between members of the project group throughout the numerous interviews. Many respondents offered to send us additional information after the interview was conducted. After each interview we sent our contact an email thanking them for their time and listing any information they had mentioned they would follow up with. Additional resources that were given to us by our contacts were analyzed alongside the interview data.

Through the interviews with both WWER vendors and previous installation representatives, we collected information on the specific technology each company and site used. The types of information we collected satisfied the data needs presented in Table 3.1 and are listed in Table 3.2.



**Table 3.2: Information Collected During Vendor and Previous Installation Interviews**

Technical	Financial	Regulatory
System flow rates: required, typical, and capacity	Cost of system equipment	Barriers that affect installation
Waste water temperature: required and typical	Cost of installaiton	Water quality regulations
System configuration	Cost of maintenance	Discharge temperature regulations
Mechanical components of system	Cost of monitoring equipment	Workforce regulations that impact maintenance
Monitoring of systems	Project funding	Regulations the limit eligibility for external funding
	Annual savings	

### **3.4 Analysis of Vendor and Previous Installation Representative Interview Data**

The data produced from the interviewing process were in the form of recorded answers to interview questions and additional notes taken by the group members during the interviews. After each interview, we compiled our notes into a single document that contained all of the interview questions and their responses. Next, one group member created a summary of the information obtained from the interview. Each interview summary specified the name and title of the contact, date and time of the interview, key terms used in the interview, a summary of the main points that were discussed during the interview, a list of the key findings from the interview, and a list of the information the contact followed up with or planned to follow up with. Group members were each responsible for writing different interview summaries throughout the project. These interview summaries can be found in Appendix C. Any additional information that a contact shared with us after the interview was also summarized in this way.

We also created a resource spreadsheet which contained information on each interview and any additional information we received. The spreadsheet contained the title of each resource, the source of the resource, a link to the resource if applicable, the summary of each resource, and citation information for each resource. An excerpt from this document can be found in Appendix G. Once we completed a number of interviews and had accumulated a significant amount of data, we reorganized our data by topic. We used Grounded Theory to “categorize content items according to the nature of the research and particularities of the data” (Berg & Lune, 2012). This was done by collecting the key findings from each interview that pertained to a certain topic, such as “Technological”, “Financial”, or “Regulatory”, and grouping them together. For example we paid particular attention to any key findings that pertained to site selection criteria. We created a spreadsheet that contained each of the criteria derived from the resource data and each source of the data that pertained to the criteria. An excerpt from this document can be found

in Appendix F. We then identified patterns and trends within the data and reflected on the meaning of these trends, offered explanations and drew conclusions from them. Other topics were analyzed in a similar manner and eventually became our findings listed in chapter 4. The information obtained through the vendor and previous installation representative interview process aided in the completion of objectives 1 and 3.

### **3.5 Waste Water Treatment Facility Representative Interview Process**

Once we had an understanding of WWER technology and the process by which WWER systems have been implemented, and had developed a preliminary list of site selection criteria based on our previous installation representative and vendor interviews, we were able to begin conducting interviews with WWTF representatives. We arranged a formal meeting with WWTF representatives with the help of our sponsors from the DOER, who already had established contacts within the industry. Before the meeting we prepared a meeting agenda, rather than preparing an interview guide, which was designed to elicit information about the sewer systems in Massachusetts and any knowledge the representatives had of potential pilot sites near the pumping stations of the sewer system. This meeting was conducted as a round table meeting. We did not assign one group member as the leader of the meeting and have the other group members take notes as we had done with the vendor and previous installation representative interviews. Our sponsors from the DOER were also present at the meeting.

We conducted the meeting with four representatives of the Massachusetts Water Resource Authority (MWRA). The MWRA had actually been interested in WWER technology before we established contacts with them. They had conducted feasibility studies of on-site WWER systems at several of their pumping stations. We collected information from the MWRA representatives about their experience with WWER technology, their concerns with the technology, and their assessment of the technology's potential for their specific applications. We also collected more general information about access to the sewer system and regulatory policy in Massachusetts that could affect the installation of WWER systems in the sewer system. After collecting all of this information, our next task was to compile it and use it to complete our project objectives.

### **3.6 Analysis of Waste Water Treatment Facility Representative Interview Data**

The data produced from the WWTF representative interviewing process were in the form of notes taken by the group members during the meeting with the MWRA representatives. After the meeting, we compiled our notes into a single document that contained all of the information we had collected. Next, one group member created a summary of the information obtained from the meeting. Each summary specified the name and title of the contacts present, date and time of the meeting, key terms used in the meeting, a summary of the main points that were discussed, a list of the key findings, and a list of the information the contacts followed up with or planned to follow up with. The MWRA meeting summary can be found in Appendix C.7. Any additional information that a contact shared with us after the meeting was also summarized in this way. The summaries and any additional information we received were added to the resource spreadsheet discussed in section 3.4.

The summaries were then analyzed in context with our other interview and resource summaries. The key findings from each summary were compared to the information obtained from the vendor and previous installation representative interview process. We identified similarities and discrepancies

between the data collected from our initial interview process and the WWTF representative interview process. We then added the information obtained during the WWTF representative interview process relevant to site selection to the document that contained each of the criterion derived from the resource data and each source of the data that pertained to the criteria, discussed in section 3.4. Similarly, the other key findings from the WWTF representative interview process were also added to the information collected from the vendor and previous installation representative interview process that the findings related to. The information obtained through the WWTF representative interview process aided in the completion of objectives 1, 2, and 3.

### **3.7 Evaluation of Potential Pilot Installation Sites in Massachusetts**

Our sponsors from the DOER also established contacts with potential installation site representatives in Massachusetts. These contacts were made with representatives of sites that the DOER knew of through contact with the MWRA or the Green Communities Division of the DOER. Since much of the information about the potential sites could be accessed without interviewing representatives of the sites, we determined that interviewing representatives of these sites would not be an effective use of the time available to complete this project.

Once we had developed a set of site selection criteria, we were able to evaluate potential pilot sites within Massachusetts. We evaluated Cambridge Martin Luther King Elementary School, Easton High School, Marlborough Town Hall, Department of Corrections' prisons, and the MWRA Ward Street pumping station area as potential pilot site locations. This evaluation included a comparison of the information we had about each site to our site selection criteria. By making this comparison, we determined whether the DOER should consider any of these sites as potential pilot sites. We also able determined what problems each site should expect to face if they installed a WWER system based on the discrepancies between their site and the site selection criteria. The information obtained through by researching potential pilot sites aided in the completion of objective 2.

### **3.8 Limitations of this Study**

Throughout the course of this project, we encountered several barriers to gaining access to the data we were seeking to collect. While our respondents chose to waive confidentiality, in some cases the respondents chose to abstain from answering certain questions. This limited the data we had access to as we conducted our interviews. We also discovered that there were not many sources of information that we could utilize to complete this project because WWER system have only been developed recently. Consequently, the market for this technology is still small, especially in North America, and there were only a few WWER vendors and installation site representatives available for our interviews. Furthermore, the sites that had installed WWER systems had only been operational for a few years. Another barrier we encountered was that the majority of the specific technical and financial information we were seeking was not available. Additionally, technical and financial specifics for a site's system we were able to obtain were highly dependent on the characteristics of specific site and could not be generalized or used to predict technical and financial specifics for potential sites in Massachusetts. For this reason, most of the data we obtained was qualitative data.

## 4.0 Results

To meet our objectives of developing a list of site selection criteria, providing recommendations for the installation of a pilot site, and identifying strategies for the future implementation of WWER, we used the data we collected to identify the aspects of an installation that make an installation site successful. For our application, we are defining a **successful site** as a site whose installation of waste water energy recovery (WWER) technology has proven to be both cost effective and energy efficient, has reduced the site's greenhouse gas emissions, and has lasted or is expected to last for the technology's estimated lifespan with reasonable ease of maintenance. The data from the five vendor interviews, one previous site interview, one WWTF meeting, and the resources provided from all of our contacts can be found in Appendix D and G respectively. As discussed in the methods chapter, responses were grouped into categories using grounded theory. In this chapter, the technical, financial, and regulatory factors we have found to contribute to the success of an installation site will be discussed, explained, and justified by our research.

**Successful site-** a site whose installation of WWER technology has proven to be both cost effective and energy efficient, has reduced the site's greenhouse gas emissions, and has lasted or is expected to last for the technology's estimated lifespan with reasonable ease of maintenance

### 4.1 Technical Factors Affecting Success

In this section, we discuss technical factors that affect the success of an installation. We are considering any factor that relates to the physical site, the WWER system, or the sewer system a technical factor. If the factor relates to the physical site, the WWER system, or the sewer system then it is discussed in this section even in cases where the factor also affects the financial viability of the system.

**Finding 1:** Successful implementations of WWER systems require ease of access to a sewage source.

It is crucial that the sewage source is sufficiently close to the application because the farther the distance between the sewage source, the WWER system, and the application, the greater the potential for heat loss and the greater the cost of operation and installation. Sufficient access can be characterized in two ways.

First, the horizontal distance between the sewage source and the application must be small. For example, a system that taps into a sewer source that is located within 400 feet of the building to be cooled will be more efficient and less expensive than a system that taps into a sewer source located half a mile away. Generally the application site should be within two city blocks of the sewage access point to remain effective (H. Russell, personal communication, September 12, 2013). Poor access increases costs and decreases efficiency. The distance the hot fluid must travel affects the efficiency of the system because when a hot surface is surrounded by an area which is colder, heat energy will be transferred from the hot surface to the cooler area. The rate of this transfer is dependent on the temperature difference and the process will continue until both the surface and the surroundings are at the same temperature. When the fluid has to travel farther, it allows more time and surface area for the cooling process to occur, thus losing more of the heat that was just recovered.

Second, the sewage source must be at an accessible depth. If the distance from the sewage pipes in depth is far from the surface, for example, 200 feet, time and money is necessary to tap into the sewage source as it is not easily accessible. This construction in order to access the sewage increases the cost of the overall project. (K. Patneaude, personal communication, September 23, 2013 and J. Wang, personal communication, September 26, 2013). In addition to increasing the installation cost because the greater pipe depth requires more drilling, deep sewer pipes would also cause operation and maintenance costs to increase because they are less accessible. The pumps that bring the sewage to the surface for the application would also consume more electricity. This finding relates to a sewer trait, and not a building trait. It cannot be used to predict the type of building that will benefit from the use of WWER technology

**Finding 2:** Wet wells of lift stations provide the best access point to the sewer system for off-site installations.

According to Geoffrey Sauter of Sewage SHARC, wet wells allow a simple and safe way to tap into the flow of sewage without directly drilling into the sewage pipes (G. Sauter, personal communication, September 3, 2013). Jimmy Wang of NovaThermal also confirmed that wet well lift stations have been found to be the best location to access the sewage needed for WWER systems. Wet wells are common in sewer systems where the sewage cannot flow against gravity (H. Russell, personal communication, September 12, 2013 and Fay, Spofford & Thorndike, 2013b). If a site desires a WWER system, and a wet well does not exist within an acceptable distance (Finding 1), then a wet well must be constructed. Constructing a wet well adds to the cost of construction and can affect the financial viability of the system. Jimmy Wang estimated that a wet well installation could cost around \$30,000 (J. Wang, personal communication, September 26, 2013). This finding does not imply anything about the types of buildings that can install WWER systems because it relates to a sewer system characteristic, not a building characteristic.

**Finding 3:** The installation of WWER systems is more financially viable at sites that are due to replace their HVAC system or need to construct an HVAC system.

When installing a WWER system, there are three possible conditions of a site's HVAC system. The site could be a new construction with no existing HVAC system, a site with an existing HVAC system that does not need to be replaced, or a site with an existing HVAC system that is due to be replaced. According to our interview with Henry Russell, a partners at Walker Wellington and a representative of HUBER technologies, the cost of installing a WWER system with pre-existing supplementary heating system is comparable to the cost of installing any other HVAC system designed to heat and cool the same site with redundancies built into the system (September 13th, 2013). Consequently, when designing a WWER system for a new construction or installing a system at a site where the old HVAC system was due for replacement, the cost of installation is something the site owner would already have to be spending on an HVAC system. Peter Nelson from Hidden Fuels, a consulting company, Kristen Patneaude from the MWRA, and a report by Vandenburg confirmed that if a site already has an HVAC system that is not due for

replacement, the cost of installing the WWER system becomes a significant expense for the site owner (P. Nelson, personal communication, September 19, 2013), (K. Patneau, personal communication, September 23, 2013 and Vandenburg, 2011).

This finding is a characteristic of a building that would be a good candidate for WWER. New construction projects are ideal; however, buildings undergoing extensive renovations, such as older buildings which are found throughout the Commonwealth, can also be a financially feasible location.

**Finding 4:** Successful WWER sites need access to a sewage source with a sufficiently high flow rate of sewage.

We have found that WWER installation sites need access to a sufficiently high flow rate of sewage in order to be successful. The flow rate of sewage depends on the time of day and season. For example, sewage flow rate is high during peak hours of water usage. The sewage flow rate is also higher during the spring when there is more water run-off. This variability in flow must be accounted for when designing a WWER system.

The specific amount of flow a site needs is dependent on the technology used and the heating or cooling load (P. Nelson, personal communication, September 19, 2013 and H. Russell, personal communication, September 12, 2013). The amount of heat energy that can be transferred to or from the waste water is dependent on both the flow rate and temperature of the waste water. We have found that while flow rate is a technical requirement, the temperature of waste water is not a technical requirement; it is instead an aspect that impacts operational costs. A useful measure for comparing different sites using WWER for space heating is the heat energy required per square foot of building space. Consequently, we can express a flow rate per square foot requirement that is consistent throughout sites. For example, the NovaThermal WWER system requires 1 million gallons per day (MGD) for every 100,000 square feet of condition space (J. Wang, personal communication, September 26, 2013). Within these parameters, the temperature of the waste water can vary, and a lower temperature would require a larger heating load on the heat pump and higher operation cost. Other systems can also express their flow rate requirements in these terms.

This finding relates to a characteristic of the sewer system. Because a WWER system requires a certain amount of flow to run effectively, a small sewer line that is fed from only a few buildings would not be a good sewage access point. For example, a sewer line that is fed by a small neighborhood would not contain a high enough flow rate to utilize WWER to heat even one of these houses. Large sewage pipes that are fed from many buildings are more likely to have a higher flow of sewage, thus making them a better access point for the sewage source to run a WWER system. This finding, however, cannot be used to conclude what type of building would make a successful implementation site because it relates to the sewer system and not the building type.

**Finding 5:** Successful WWER implementation requires access to a sewage source with a temperature within the range of the operating temperature of the system's heat exchanger.

In order for WWER to be a viable technology, the waste water needs to be compatible with the heat exchanger technology (P. Nelson, personal communication, September 19, 2013). Each heat exchanger requires specific temperatures to operate at their desired coefficient of performance (COP). It is most beneficial if the temperature of the waste water falls within the operating range of the heat exchanger (J. Wang, personal communication, September 26, 2013). For example, according to the MWRA, the waste water must fall within the temperature range of 50 F and 85 F for the heat exchangers used in their systems to operate efficiently (Fay, Spofford, & Thorndike, 2013a). This finding describes a characteristic of the sewer system. It is important that the building considering implementation of WWER has access to a sewage source of this nature, but it does not imply anything about the types of buildings that are more or less suitable.

**Finding 6:** Successful WWER implementation sites require access to a sewage source with a sufficiently high temperature for heating applications or a sufficiently low temperature for cooling applications.

The temperature of the waste water affects the operating costs of the WWER system. The higher the initial temperature of the waste water in a heating application, the less the heat pump will need to heat the fluid after heat exchange and the lower the operating cost for the system. Similarly, the lower the initial temperature of the waste water in a cooling application, the less the heat pump will need to cool the fluid after heat exchange and the lower the operating cost for the system (J. Wang, personal communication, September 26, 2013).

While taking Finding 5 into account, for a heating system to be successful the waste water temperature must be as high as possible while remaining within the operating range of the heat exchanger, and for a cooling system to be successful the waste water temperature must be as low as possible while remaining within the operating range of the heat exchanger. This finding describes a characteristic of the sewer system. It is important that the building considering implementation of WWER has access to a sewage source of this nature.

**Finding 7:** WWER systems are typically more efficient when used for cooling applications.

We have found that WWER systems typically have higher coefficients of performance (COPs) when used for cooling applications than they have when used for heating applications. As discussed in section 2.1, the COP in either a heat pump or complete WWER system is the ratio of heat energy yielded to the electrical energy consumed. High COPs indicate low operating costs because the less electricity the system consumes to transfer heat, the less the system will cost to operate. Therefore, the user of a WWER system will incur lower operating costs while the system is being used for cooling rather than heating. NovaThermal's WWER system is an example of a system that follows the trend of having a higher cooling COP and lower heating COP. The COPs of the heat pumps used in the NovaThermal system for heating are between 3.5 and 4.5, with larger units typically having higher COPs than smaller units. The COPs of NovaThermal's

complete systems when used for heating, which account for the electricity used to run the filtration system in addition to the electricity used to run the heat pump, are typically around 3.2. The COPs of the heat pumps used in the NovaThermal system for cooling are between 5.0 and 6.0. The COPs of NovaThermal's complete systems when used for cooling are typically around 5.2 (J. Wang, personal communication, September 25, 2013). These data are summarized in Table 4.1.

**Table 4.1: Trends in COPs Using NovaThermal as an Example**

<b>Trends in COPs Using NovaThermal as an Example</b>			
Heating COP		Cooling COP	
Heat Pump Only	3.5 to 4.5	Heat Pump Only	5.0 to 6.0
WWER System	3.2	WWER System	5.2

This trend appeared in the HUBER systems as well (HUBER, 2013). While this finding does not directly relate to a building characteristic, it does show that buildings with a large cooling load, such as an ice rink or a refrigerated warehouse, would benefit from a cooling application of WWER.

**Finding 8:** The operation and maintenance of WWER systems is not likely to be a barrier to the success of an installation.

As noted in section 2.4, WWER technology is not new technology; it is a well-established technology being used for a new application. The components in WWER systems are only modified slightly in order to be used in WWER applications. For example, HUBER's heat exchangers used in WWER recovery have wider channels to prevent clogging (C. Hubbard, personal communication, October 3, 2013). WWER systems should not prove to be difficult to operate or maintain because the components of the systems are all familiar technology to the maintenance personnel that maintain the sewer systems (H. Russell, personal communication, September 12, 2013, C. Hubbard, personal communication, October 3, 2013 and J. Wang, personal communication, September 26, 2013). International WWER vendors also intentionally use American components in their American installations so the technology can be maintained by personnel that are familiar with the components (C. Hubbard, personal communication, October 3, 2013).

Thorough maintenance of the systems requires the complete shutdown of the system. However, complete shutdown is not expected to be needed often. HUBER systems are expected to need to be shut down for maintenance only 2-3 days out of the year (C. Hubbard, personal communication, October 3, 2013). This includes periodic maintenance to make sure the components are functioning properly. Every 3-5 years, the screen needs replacement, which will cost the owner anywhere from \$300-\$500 depending on which screening mechanism is in place. The electric motors in the pumps will need to be serviced or replaced every 5-6 years. A motor generally costs less than \$500 (H. Russell, personal communication, September 12, 2013).



**Finding 9:** The presence of existing monitoring equipment in the nearby sewer simplifies the installation process.

The installation of WWER systems usually requires a scoping project, which evaluates the flow rates and temperatures of the waste water in the area around the site (P. Nelson, personal communication, September 19, 2013). These scoping projects can be expensive depending on their scale. The cost of a scoping project for a single building is usually on the order of thousands of dollars, while the scoping project for a very large district could be on the order of hundreds of thousands of dollars (P. Nelson, personal communication, September 19, 2013). The cost of these scoping projects can be reduced if equipment that monitors flow rate and temperature has already been installed in the sewer system. Such equipment is sometimes installed for use by the sewer company that maintains the sewer system (Boston Water and Sewer Commission, 1998). Sites that already have monitoring equipment installed can benefit from reduced cost of installation.

This finding describes characteristics of the sewer system and a potential installation site. Although it is important for a building to have access to this information, these data collected by the monitoring equipment indicate more about the sewer system than the building.

## 4.2 Financial Factors Affecting Success

In this section, we discuss financial factors that affect the success of an installation. Here we are considering only the aspects that relate to the financial viability of an installation and do not relate to the physical site, WWER system, or sewer system. In general, the cost of installation of a WWER system is responsible for a high upfront cost. To be successful, the combined cost of operation and maintenance of a system must then be lower than the cost for heating or cooling the site prior to installation. The financial aspects that affect success (and the technical aspects discussed above that have financial consequences) all deal with lowering installation, operation, and maintenance costs or otherwise increasing the savings incurred by installing the WWER system.

**Finding 10:** WWER systems are more financially viable if used year-round.

Year-round WWER system use is more financially viable because successful WWER systems have both higher upfront costs and lower operating costs compared to fossil fuel based HVAC systems. If the system is used frequently and for a long enough period of time, the savings incurred by using the WWER system will eventually overcome the difference in installation cost. The point in time when the savings incurred by the use of the system balance out the installation cost of the system is the payback period for the system. After the payback period is reached, the system begins saving its owner money even when accounting for the system's installation cost. Equation 4.1 is an equation for calculating payback period that accounts for the cost of maintenance.

$$P = \frac{I}{O_1 - O_2 - M}$$

**Equation 4.1 Payback Period Calculation**

In this equation, P represents the payback period in years. I represents the cost of installation including the scoping project, equipment cost of the system, and design of the system.  $O_1$  represents the operational cost of the original HVAC system per year.  $O_2$  represents the operational cost of the WWER system per year. M represents the cost of maintenance of the WWER system per year. If the term  $(O_1 - O_2 - M)$  is a negative quantity, then the numerical result of the calculation will be meaningless. If this occurs, then the site will not reach a payback period. The quantities needed for this calculation will need to be estimated based on the findings of the scoping project.

If a WWER system is operated year-round, it will have a shorter payback period than a WWER system that is only used during part of the year. According to a study conducted by the Massachusetts Water Resources Authority (MWRA), “for any heat recovery system to achieve the lowest life cycle cost possible it needs to operate continuously” (MWRA, 2013). In Colorado, designers of a district heating system recognized that a year-round demand for the use of the system was beneficial and adopted strategies to use the system year-round for heating pools, heating buildings, and melting snow (Vandenburgh, 2011), year-round use of the WWER system results in a shorter payback period because the savings incurred by using the system are dependent on the amount of time the system operates. This finding implies that buildings with year-round heating and cooling loads such as cold storage warehouses, electrical rooms, and hockey rinks are likely to be financially viable. If the system is not operated year-round, it is possible that the system will be due for replacement before its payback period has been reached.

**Finding 11:** The financial viability of an installation is affected by the cost of the fuel source that is replaced by the system.

HVAC systems use a variety of different fuel sources, and each of these fuel sources have different costs. For example, heating a site using natural gas is much less expensive than heating a site using electricity (K. Patneade, personal communication, September 23, 2013 and Fay, Spofford, & Thorndike, 2013a). When installing a WWER system, the financial viability of the system depends on the system’s ability to reach its payback period. The payback period calculation (Equation 4.1) includes a term which depends on the amount of money the owner of the system saves by using the system instead of another HVAC system. If an HVAC system that used an inexpensive fuel source was replaced by a WWER system, then the savings incurred by the WWER system will be less than they would be if a more expensive fuel source was replaced. Consequently, the system will have a longer payback period and will be less financially viable in this case. During their analysis of several of their pumping stations as potential WWER installation sites, the MWRA was able to confirm that the payback period of sites that use natural gas, an inexpensive energy source, would be longer than sites that use fuel oil or electric heating, more expensive energy sources (K. Patneade, personal communication, September 23, 2013).

**Finding 12:** The financial viability of the installation is affected by the cost of electricity at the site.

Because these WWER systems use heat pumps to increase the system’s ability to effectively be used for heating and cooling, electricity costs have to be taken into consideration (Fay, Spofford & Thorndike, 2013b). The cost of electricity is a factor that influenced financial models, such as payback period, and had an effect on WWER systems’ financial viability. Depending on the size

of the application, the electricity necessary to run the heat pumps could be a factor. Electricity costs vary between regions of the country, between states, within the states themselves, and even during different times of the day. Therefore, cost savings related to WWER also vary. For example, if the installed pump takes X amount of electricity to run an hour is installed in both location A and location B, and location A has an energy rate of \$0.10 per kWh while location B has an energy rate of \$0.14 per kWh, location B will spend more money annually on pump operations, therefore, the system's payback period is increased (Fay, Spofford, & Thorndike, 2013 and McCormick, Carkrabari, & Liner, 2012). Consequently, WWER systems installed in areas with lower electricity costs are more likely to be financially viable.

**Finding 13:** WWER systems are more financially viable if grants or tax rebates are available.

For WWER to be financially viable, most sites that were studied required a source of outside funding, such as grants or tax rebates, to offset the high startup costs. These costs include the planning process in addition to the installation and construction costs. These costs vary case by case, which makes it difficult to predict a "typical" cost situation. For example, a smaller scale scoping project costs \$5,000-\$15,000 to map the amount of energy present in the waste water. However, if this technique was applied to the entirety of a city as large as Boston it could cost hundreds of thousands of dollars (P. Nelson, personal communication, September 19, 2013). Some sites spend a large amount of their costs on the components of the WWER system itself. Kent County spent around \$400,000 on its heat pumps (J. Newton, personal communication, September 9, 2013), while other components of WWER systems can cost between \$200,000 and \$300,000 depending on size. (C. Hubbard, personal communication, September 25th, 2013). In other cases, construction costs could amount to about \$400,000 (Fay, Spofford & Thorndike, 2013 and G. Sauter, personal communication, September 3, 2013). Without financial assistance, the payback period of the WWER system becomes longer, and the installation becomes less likely to be financially viable (Fay, Spofford & Thorndike, 2013).

**Finding 14:** There are two financial models available for WWER systems: private ownership, and third-party ownership.

One financial model available for WWER systems is private ownership. This means that the user buys and owns the system, is responsible for its maintenance, and receives all of the savings associated with owning the system. In some cases the "user" is a public agency and not an individual building owner. The benefits of using this model are that the model is familiar to potential users because most HVAC systems use this model, the user has control over the maintenance of the system, which is beneficial because the system is located on their site, and the user receives the full savings associated with using the system, rather than having to pay a third party for the energy supplied by the system. The drawbacks of using this model are that the high upfront cost of the system is borne by the user and the user is responsible for maintaining the system. The installations we have researched have all used this model and have found it to be beneficial. The Kent County installation for example, privately owned and maintained their system and benefitted from the savings the system provided (J. Newton, personal communication, September 9, 2013). HUBER's and NovaThermal's installations have also used this model (C.

Hubbard, personal communication, October 3, 2013), (J. Wang, personal communication, September 26, 2013). HUBER also offers warranties or service contracts to alleviate the burden on the user of maintaining the system (C. Hubbard, personal communication, October 3, 2013).

The other financial model available for WWER systems is third party ownership. This means that a third party buys and owns the system and is responsible for its maintenance. This party then allows the user to receive energy from the system and is financially compensated for the system's use. The benefits of using this model are that the user of the system does not incur the large upfront cost associated with privately installing the system and the user is not responsible for the maintenance of the system. The drawbacks of using this model are that user has no control over the maintenance of the system and the user must pay the third party for the energy supplied by the system rather than receiving the full savings associated with owning the system. This financial model is likely to be beneficial in district heating applications (B. Douglas, personal communication, October 2, 2013).

### **4.3 Regulatory Factors Affecting Success**

There are several regulations in place affecting the sewer systems of Massachusetts. These regulations do not specifically address WWER. However, they affect the installation of WWER systems that use sewage. Because WWER systems remove the sewage, alter it by filtering it and changing its temperature, and then return both the solid and liquid material to the sewer system, the WWER systems must comply with the regulations affecting sewage discharge. Additionally, Massachusetts has regulations related to the modification of or addition to sewer equipment. As an example, the regulations set by the Boston Water and Sewer Commission are discussed in detail below. These are the specific regulations that must be considered when installing WWER systems within the Boston sewage district. Other sewage districts within Massachusetts have their own similar regulations that pertain to their own districts.

**Finding 15:** Sites installing WWER systems must take precautions to ensure that the system will not interfere with the treatment process or alter the waste water significantly and make their plans known to the Commission prior to applying for a permit.

Article 1, Section 9 of Regulations Governing the Use of Sanitary and Combined Sewers and Storm Drains (Boston Water and Sewer Commission, 1998) may affect the implementation of WWER systems in the City of Boston. Article 1 section 9 states:

The Commission may refuse to issue a permit for any discharge which it believes can reasonably be expected to result in significant harm to health, safety, the environment, the Commission's wastewater or storm drainage system, a tributary to the Commission's wastewater or storm drainage system, or may pass through, interfere with, or otherwise be incompatible with the wastewater treatment process or sludge disposal (Boston Water and Sewer Commission, 1998).

If the Commission determines that the installation or operation of a WWER system may cause significant harm or interfere with the waste water system or waste water treatment process by altering the waste water's temperature or disrupting sewage flow, then they could stop the process indefinitely by refusing to issue permits for the project to begin.

**Finding 16:** The use of all public sewers in the City, potentially including use by WWER system owners, shall be overseen by the Boston Sewer and Water Commission (BSWC).

Article II, Section 1, 3 and 6 of Regulations Governing the Use of Sanitary and Combined Sewers and Storm Drains address the use of public sewers in the City of Boston. Article II Section 1 states:

The use of all public sewers in the City, except interceptors of the MWRA's wastewater system, shall be controlled by the Commission. No person shall, without prior authorization from the Commission, uncover, excavate over, block access to, make any connection with or opening into, alter, or disturb the Commission's wastewater or storm drainage systems (Boston Water and Sewer Commission, 1998).

Article II Section 3 states: "No person shall enter or install equipment into the Commission's wastewater or storm drainage systems without first obtaining from the Commission a Permit to Enter Commission Sewers" (Boston Water and Sewer Commission, 1998).

Article II Section 6 of Regulations Governing the Use of Sanitary and Combined Sewers and Storm Drains states:

When required by the Commission a user shall design, construct, install, operate and maintain special facilities which will provide for the regulation and control of the rate, volume and characteristics of wastewater discharged to the Commission's and MWRA's wastewater system or storm water to the Commission's storm drainage systems... Such special facilities shall be designed, constructed, operated and maintained at the owner's expense (Boston Water and Sewer Commission, 1998).

Any applications for permits regarding access to the sewer system for the installation of WWER systems must be reviewed and approved by the BSWC. These regulations make clear how to obtain access to the sewer system and who is responsible for maintaining specific features of the sewer system.

**Finding 17:** The BSWC must give written approval for any changes to be made to the sewer system, but any costs associated with installing a WWER system would fall in the hands of the permit applicant or owner.

Article III, Sections 6, 19 and 20 of Regulations Governing the Use of Sanitary and Combined Sewers and Storm Drains address who controls the sewer system, and who is responsible for the costs associated with any changes or repairs. Article III Section 6 States: "Building sewer connections for new or substantially rehabilitated buildings shall not be made directly to Commission-owned manholes unless expressly authorized in writing by the Commission" (Boston Water and Sewer Commission, 1998). This means that the installer of the WWER system needs approval by the BWSC to install the WWER system.

Article III Section 19 of Regulations Governing the Use of Sanitary and Combined Sewers and Storm Drains states:

All costs and expenses incidental to the application form, design, construction, installation, connection, repair, and maintenance of a building sewer, building storm drain, other private sewers, special facilities, particle separators, grease traps, oil traps, or other wastewater or storm drainage facilities shall be borne by the owner (Boston Water and Sewer Commission, 1998).

Article III Section 20 of Regulations Governing the Use of Sanitary and Combined Sewers and Storm Drains states:

Any person may propose an extension, replacement or relocation of a Commission sewer to serve a new or rehabilitated building... Extension, replacement or relocation of a Commission sewer shall not commence without the Commission's prior written approval... All expenses incurred pursuant to the extension, replacement or relocation of a Commission sewer including but not limited to application, engineering, legal, permitting, construction and inspection costs, shall be borne by the applicant (Boston Water and Sewer Commission, 1998).

This can be applied to WWER because the commission would have to give permission for the project to tap into the sewer, but the BSWC would not be responsible for costs. The whole of the project expenses would be paid for by the project applying for the permits. For example, the DOER would be responsible for any costs associated with installing a WWER pilot system.

**Finding 18:** A WWER user must install suitable control or measuring devices when required by the BSWC or the MWRA.

Article IV Section 3 of Regulations Governing the Use of Sanitary and Combined Sewers and Storm Drains addresses the issue of monitoring devices used for data collection within the sewers. Article IV Section 3 states:

When required by the Commission or the MWRA, a user shall install suitable control or measuring devices together with manholes, chambers, meters, and other appurtenances in its building sewer(s), or building storm drain(s) to facilitate discharge observation, monitoring, sampling and measurement (Boston Water and Sewer Commission, 1998).

This requirement is relevant to WWER systems because we have found that it is beneficial to have monitoring devices already in place before a WWER system is installed. Having data readily available reduces the time of the planning process and reduce the cost of installing these devices. If these monitoring devices were required by the Commission or the MWRA, there would be more data available for WWER system planning as well as other applications. However, installation sites would also likely be required by the Commission to install these monitoring devices within their WWER systems.

**Finding 19:** The BSWC must be notified in advance by a WWER system installer of any plans that may affect the sewer systems that they preside over.

Article VI: Section 3 of Regulations Governing the Use of Sanitary and Combined Sewers and Storm Drains states:

A permittee shall provide at least 30 days advance written notification to the Commission before taking any action which may substantially change the volume or nature of its discharge... Such actions may include... modification of any process; ...alteration of the pretreatment system or the operation of the pretreatment system; ... discharge from a different or relocated sewer connection (Boston Water and Sewer Commission, 1998).

It is important for WWER system owners to consider that this must be in writing and provided to the Commission prior to taking action.

**Finding 20:** Under the current APS regulation, WWER does not qualify for funding.

As discussed in Finding 13, external funding for WWER systems greatly reduces the upfront cost of the systems and enables the systems to reach their payback periods earlier. However, under the current APS regulation, WWER systems do not qualify for alternative energy credits (Massachusetts Department of Energy Resources, 2012 and Veilleux, 2011). The types of projects that can be funded using state programs are limited by both the type of technology that is being installed, and the fuel source that is being replaced (Massachusetts Department of Energy Resources, 2012). Unless regulations are modified to include WWER technology as eligible technology, the upfront costs of these systems will inhibit their implementation in Massachusetts.

**Finding 21:** There are concerns that WWER technology may cause contamination, negatively affect the treatment process, or clog the sewage system, which may result in regulation in the future.

While there are numerous regulations that could pertain to WWER systems within sewer systems, the regulations that relate specifically to WWER technology are currently sparse. This is because WWER technology is new and has not been considered by many of the agencies responsible for its regulation (P. Nelson, personal communication, September 19, 2013). As this technology becomes more prevalent, several potential concerns with the technology could become regulated.

One potential concern is that the use of waste water as a heat source for potable water could lead to contamination. This is not likely to be a concern with WWER systems that are functioning as intended because the fluids in heat exchangers and heat pumps do not come into contact (Bergman & Incropera, 2011). Contamination has not occurred in any of the cases we researched. The systems will need to be properly maintained in order prevent contamination and avoid any regulatory issues that contamination could cause.

A second potential concern with using WWER technology is that the systems could affect the temperature of the sewage in a way that makes treatment more difficult. However, a system would have to remove or add a very large amount of heat in order to substantially affect the sewage temperature. According to the MWRA, the temperature difference likely to occur through the use of a WWER system will not be sufficient to affect sewage treatment (K. Patneade, personal communication, September 23, 2013).

A third potential concern is that WWER systems may clog and disrupt sewage flow (K. Patneade, personal communication, September 23, 2013). The solid-liquid separation mechanism within the WWER system must be selected with this in mind and sufficiently maintained in order to prevent clogs from occurring. Other components within the system can

also be modified to prevent clogging. For example, HUBER WWER heat exchangers are designed with wider channels to allow unfiltered solid particles to pass through (C. Hubbard, personal communication, October 3, 2013).

#### **4.4 Social Factors Affecting Success**

**Finding 22:** Collaboration between all of the parties involved in the installation of WWER systems has been difficult to facilitate in previous projects.

The installation of WWER systems requires collaboration between the site owner, sewer system owners, and any government agencies aiding in the installation process. According to Chris Hubbard, a representative of HUBER, one of the largest difficulties faced in the installation process is getting all of these parties to communicate and work together (C. Hubbard, personal communication, October 3, 2013). A representative of NovaThermal also noted that often these parties do not agree at certain points throughout the installation process, and this can greatly inhibit a system's installation (J. Wang, personal communication, September 26, 2013). In order for WWER systems to be implemented successfully, all of the parties involved in a system's installation must be able to collaborate effectively.



## 5.0 Conclusions and Recommendations

This chapter discusses the main conclusions of our project: the site selection criteria. These criteria can be used to evaluate site potential in order to determine ideal and high potential future implementation sites. The discussion includes an examination of each criterion individually, the priority given to each criterion and the method of evaluating sites through the use of these criteria. Next we discuss our recommendations for the Department of Energy Resources (DOER), including an in depth explanation of the recommended site implementation process. We also discuss recommendations the DOER should provide to parties interested in installing WWER technology and as well as future steps to promote WWER in Massachusetts.

### 5.1 Site Selection Criteria

Our main project conclusion was the development of site selection criteria for the implementation of WWER. These criteria address technical, economic, and social factors. We then determined the ideal case for each criterion. We prioritized the criteria from most to least important. These criteria, their ideal case, and their priority are listed in Table 5.1.

**Table 5.1: Site Selection Criteria**

Criteria	Ideal Case	Priority
Access to sewage source	Sewage source close to application and surface	1st- make or break due to technical limitations
Status of existing HVAC system	New construction or total system replacement	1st- make or break due to financial limitations
Heating and cooling load	Constant year round demand	3rd- highly desirable for financial reasons
Sewage flow rate	High when compared to energy need	4th- highly desirable for technical reasons
Sewage access point	Wet well or lift station	5th- highly desirable but not required
External funding	Grants or tax rebates available	6th- not required but greatly reduces cost
Energy source replaced or supplemented	High cost energy source such as electric heating	7th- not required but greatly reduces cost
Electricity cost	Low cost per kWh	8th- not required but reduces operating cost
Sewage temperature	Consistently in operating range of heat exchanger	8th- not required but increases efficiency which reduces cost
Monitoring System at or Near the Site	Sewage data available prior to installation	10th- not required but reduces the cost of scoping project

The criteria in Table 5.1 are separated into three blocks according to their importance. The red block contains the highest priority criteria that must be met in order to proceed with the installation of a WWER system.

**Criterion 1:** The site must be in close proximity to a sewage source.

Before installing a WWER system, the site's ability to access to a sewage source must be evaluated. Ideally, the sewage access point should be within two city blocks of the site (Finding 1). The sewage source must also be at a depth from the street level that is accessible for installation and maintenance. This criterion is of highest priority because if it is not met, then the installation of a WWER system would not be worthwhile.

**Criterion 2:** The site must be a new construction or have an HVAC system that is due for replacement.

Before installing a WWER system, the HVAC system at the site must be evaluated. The ideal case for this criterion is that the site is a new construction or has an HVAC system that is due for replacement. For new construction and HVAC system replacement, building owners will be incurring some cost for the installation of an HVAC system regardless of the type of system they are installing. Consequently, installing a WWER system will not be a large financial burden on the building owner under these circumstances. However, if the site already has an HVAC system that is not due for replacement and the site owner has no reason to invest in an HVAC system, then the cost of installing the WWER system becomes a significant expense for the site owner (Finding 3). This criterion is of highest priority because if it is not met, the site owner will incur substantial expenses and the installation will not be financially feasible.

The yellow block in Table 5.1 contains high to moderate priority criteria that should be met in order to install the WWER system but meeting them is not absolutely necessary for installation. Failing to meet these criteria will cause substantial financial or technical problems for the installation site.

**Criterion 3:** The site should have a year-round heating and cooling load.

Before installing a WWER system, the heating and cooling load at the site must be evaluated. Ideally, the heating and cooling load should be year-round. As discussed in Finding 7, WWER systems function more efficiently when they are used for cooling applications. However, the system can be used for heating, cooling, or both, depending on the season, as long as the system is being used frequently. A constant heating and cooling load improves the financial viability of a WWER system (Finding 10). This criterion is of high priority because if there is no full time heating or cooling load, then the payback period will be substantially longer, potentially resulting in the scenario where the payback period is longer than the lifetime of the system.

**Criterion 4:** The site must have access to a high flow rate of sewage.

Before installing a WWER system, the flow rate of available sewage must be evaluated. The flow rate a site requires will vary greatly depending on the site. The ideal case for this criterion is that the sewage flow rate is greater than or equal to the flow rate required to meet the heating or cooling load of the site (Finding 4). The flow rate of sewage at a single location varies over time, and this must be accounted for when evaluating the potential for the sewage source to serve as an energy source for the site. This criterion is of moderate priority because failing to meet the site's flow rate requirement results in the need for a backup or supplementary heat source, increasing the payback period of the system.

**Criterion 5:** The site should access the sewage from a wet well or lift station.

Before a WWER system is installed, the access point to the sewage used at the site must be evaluated. Ideally, a site would access sewage at a wet well lift station. Although there are other options for sewage access, wet well lift stations provide the sewage access needed for installation and maintenance of a WWER system in a way that is both simple and safe (Finding 2). Wet well lift stations tend to be common in sewer systems. If an existing wet well can be utilized, the

WWER system would not need to construct an access point, thus saving on installation costs. This criterion is of moderate priority because other access options exist but they are more expensive or make access more difficult.

The green block in Table 5.1 contains low priority criteria that are beneficial to meet but are not required for installation. Failing to meet these criteria will increase the payback period for the installation of the WWER system.

**Criterion 6:** Owners of a site should obtain external funding and subsidies.

Before installing a WWER system, the availability of external funding provided for the site must be evaluated. The ideal case for this criterion is that a significant portion of the expenses related to the installation of the system are covered by grants or other sources of external funding. When the owner is responsible for a smaller portion of the financial load, the payback period becomes shorter (Finding 13). This criterion is of low priority because it is beneficial to meet but failing to meet it does not prevent the installation of the WWER system. If this criterion cannot be met, then the payback period will be increased.

**Criterion 7:** The site should use the WWER system to replace or supplement a high cost energy source.

Before a WWER system is installed, the energy source the system replaces or supplements must be evaluated. Ideally, the WWER system should replace or supplement a high cost energy source such as heating oil. This case is ideal because WWER systems reach their payback period by saving their owner money over time. The greater difference between the cost of the original energy source and the cost of using WWER, the shorter the payback period of the system (Finding 11). This criterion is of low priority because it is beneficial to meet but failing to meet it does not prevent the installation of the WWER system. If this criterion is not met, then the payback period of the system will be increased.

**Criterion 8:** The local cost of electricity at the site should be low.

Before installing a WWER system, the cost of electricity at the site needs to be evaluated. Ideally, the electricity cost should be low. The WWER system uses electricity to run some of its components, including the solid liquid separation mechanism, pumps, and heat pump. Consequently, the electricity cost must be reasonably low in order to reduce the operating cost of the system. Electricity costs vary by location and time of day and must be evaluated on a case by case basis. The higher the electricity rate, the longer it takes to reach the payback period (Finding 12). This criterion is of low priority because it is beneficial to meet but failing to meet it does not prevent the installation of the WWER system. If this criterion is not met, then the payback period of the system will be increased. In Massachusetts electricity rates are comparatively high, which could be a barrier to implementation of WWER systems in the Commonwealth (Energy Information Administration, 2013a).

**Criterion 9:** The temperature of the sewage must meet the temperature required for the application and be within the operating range of the heat exchanger.

Before installing a WWER system, the temperature of the sewage available at the site must be evaluated. The ideal case for this criterion is that the temperature of the sewage is either high or low enough for the application and within the optimal range for the heat exchanger. The temperature of the sewage must be as high as possible for a heating application and as low as possible for a cooling application because the closer the temperature of the sewage is to the desired outlet temperature, the less electricity the system will need to use and the lower the operation costs will be (Finding 6). However, the temperature cannot be too high or low because it must also be within the operating range of the heat exchanger or the system will not operate efficiently (Finding 5). This criterion is of low priority because it is beneficial to meet but failing to meet it does not prevent the installation of the WWER system. If this criterion cannot be met, then the operational costs of the system will increase and the payback period of the system will be increased as a result.

**Criterion 10:** The site should be in a location where the sewage system has monitoring equipment installed.

Before installing a WWER system, monitoring systems at or near the site need to be evaluated. Ideally, monitoring systems will have been installed and collected data prior to installation at the site. If there is no available data before the system is installed, in order to conduct a scoping project, data must be collected and monitoring systems must be installed before installation can begin, adding to the cost of the installation.

If the monitoring system does not exist before the project to install a WWER system begins, then these monitoring systems will have to be installed, again adding to the cost of the system (Finding 9). This criterion is of low priority because it is beneficial to meet but failing to meet it does not prevent the installation of the WWER system. If this criterion cannot be met, then the installation cost of the system will increase and the payback period of the system will be increased as a result.

We have also developed a means of evaluating a potential site using these criteria. This evaluation process is represented as a flowchart in Figure 5.1.

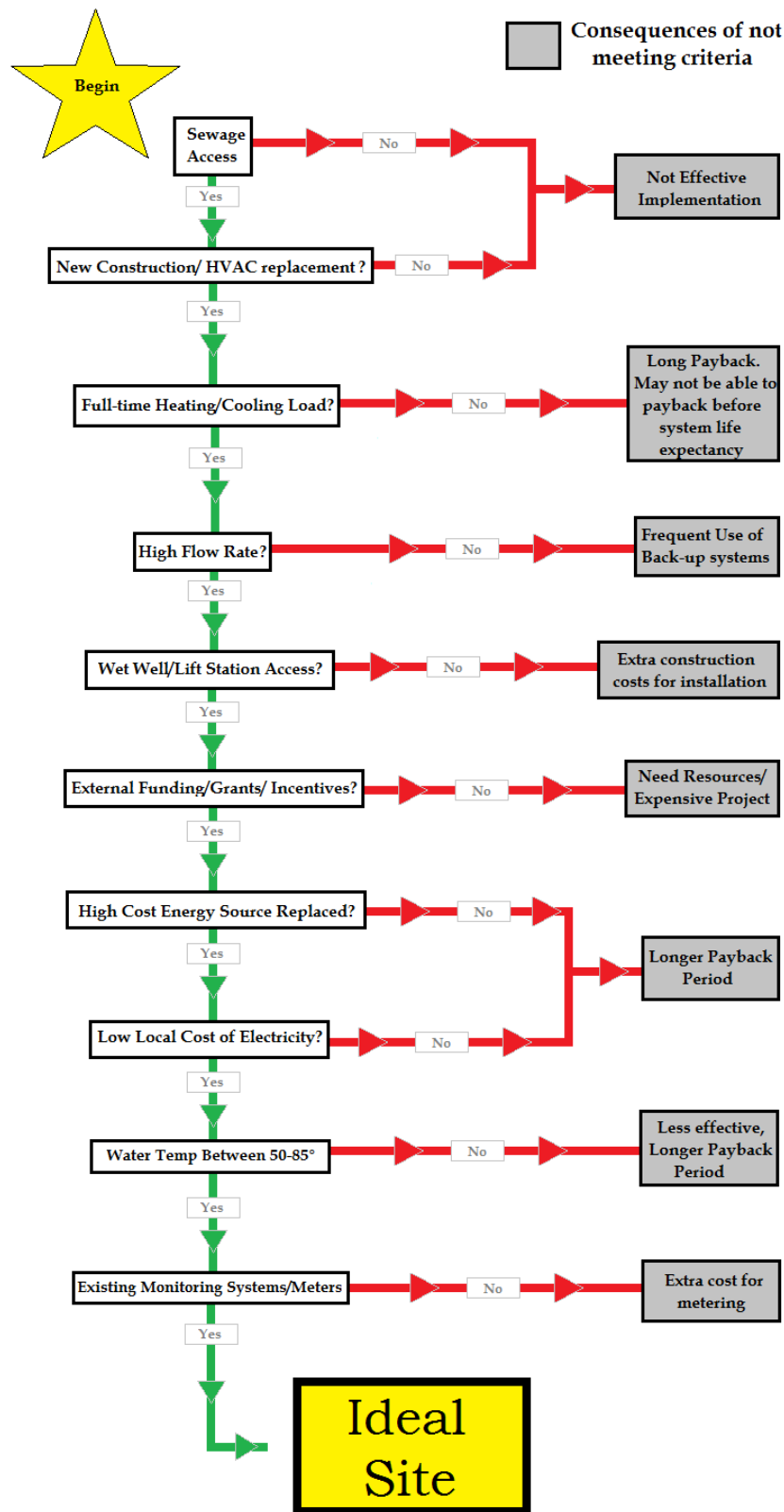


Figure 5.1: Site Evaluation Process

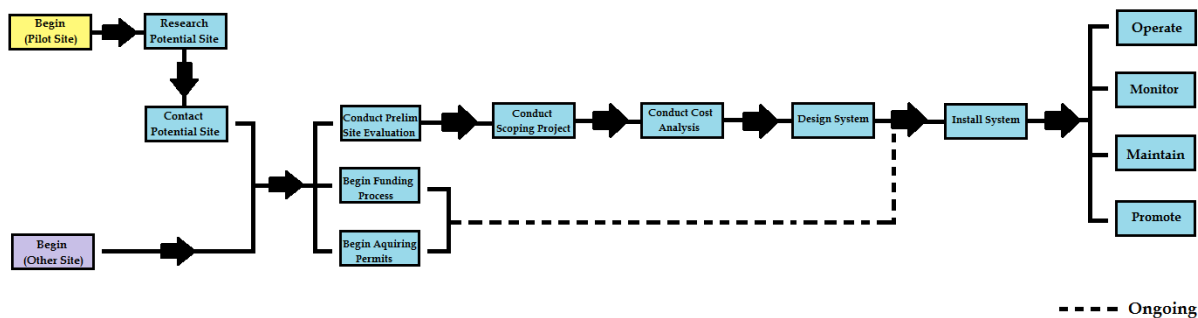
In this process, a site is evaluated in terms of each of the above criteria. If the site meets the criterion, then the user of the flowchart moves on to the next criterion. If the site does not meet the criterion, then the consequence of failing to meet the criterion is described. Some of the criteria, such as Criterion 2, are binary; a site will either meet these criteria or it will not. Other criteria, such as Criterion 7, can be evaluated on a spectrum. In this case, the degree to which the site deviates from these criteria will affect the severity of the consequence of failing to meet the criteria. Depending on the severity of the consequence for failing to meet each criterion, the user of the flowchart can then determine if the installation should be pursued.

## 5.2 Recommendations for the Selection and Installation of a Waste Water Energy Recovery Pilot Site

Installing a pilot site within Massachusetts is an integral part of promoting WWER throughout the Commonwealth. One of the benefits of installing WWER at a pilot site within Massachusetts is that the site can be used to educate potential users of the technology about WWER and encourage the public to install the technology in other locations. Another benefit of installing WWER at a pilot site is that by installing and maintaining the system, the DOER can confirm the viability of the technology and modify regulatory policies to facilitate its implementation and funding. In this section, we discuss the steps that should be taken by the DOER in order to install a WWER system in a pilot site.

**Recommendation 1:** Use the process presented below for the selection and installation of a pilot site.

We have developed a process that the DOER should follow in order to install a WWER system in a pilot site within Massachusetts. In this section, we will discuss each step of this process and explain the justification for the step's completion. We recommend that the DOER follow this process when selecting and installing a pilot site. The pilot site installation process is outlined in a flowchart in Figure 5.2. Figure 5.2 also shows the installation process for sites that will install WWER systems after the installation of the pilot site. This process will be discussed in section 5.3.3. The final step in the pilot site selection and installation process, promotion, will be discussed in section 5.3.1.



**Figure 5.2: Pilot Site Installation Process**

*Step 1: Research potential sites.*

Many communities throughout the Commonwealth are taking steps to implement renewable and alternative technology. These communities may have implemented renewable technologies in the past and are seeking more installation opportunities. Communities already interested in renewable technologies are excellent places to begin the search for implementation sites for WWER. The DOER should work in conjunction with the Green Communities Division to reach out to sites that might have interest in a WWER project. Once a community that has shown interest in renewable technologies in the past has been identified, the next step would be to gather a list of buildings within the community and evaluate each site with the criteria provided. Once a potential site has been identified, we recommend that the DOER research the site and, to the best of their ability, collect information to fill in the data gaps so the site can be evaluated using the criteria outlined in Figure 5.1.

*Step 2: Contact potential sites.*

When contacting the representative of a potential site, such as a building owner, company manager, or municipality director, it is important to define the problem and its context. The DOER should supply the potential site with information about the DOER, WWER, and why its installation should be considered, referring back to the list of criteria presented. By contacting the site, the DOER should also obtain any information on the site that they can at that time to evaluate the site's potential for effectively installing WWER technology.

*Step 3: Use criteria to evaluate potential sites.*

If a site expresses interest in WWER, the first step is to systematically evaluate the site using the site selection criteria. This evaluation should be performed using the flowchart presented in Figure 5.2. When selecting a pilot site to pursue, the DOER should perform this evaluation on a number of sites and choose to move forward with the site that best fits the criteria for site selection. The DOER may not be able to complete the evaluation of the site in terms of each criterion at this time, but they should complete as much of the evaluation as possible before selecting a site to pursue.

We began taking the steps described above as part of this project. So far we have considered several sites as potential pilot sites for the installation of a WWER system. For each site we completed steps 1 through 3 of the Pilot Site Installation process, meaning we have researched, contacted, and evaluated these sites in terms of our criteria. Summaries of our evaluations for each site follow.

- The MLK School in Cambridge originally appeared to be an excellent location for the implementation of WWER because it was a new construction. After further review and communication with location contacts, we realized the project was already in a final design stage and had already gone out to bid for the ground-source heat pumps. Thus this project was too far along to incorporate WWER in a financially feasible manner.

- Marlborough Town Hall looked to be a good location for implementation of WWER because it has preexisting water source heat pumps that could be modified to use waste water as the energy source. Preliminary outreach was not successful within the timeframe of this project.
- A high school in Easton, MA appeared to be an acceptable location for WWER. Communication was established with the Department of Public Works. There is a Waste Water Treatment Facility at the location, but initial conversations indicated low flow of sewage during summer months, indicating that criterion 4 would not be met. This site indicated preliminary interest in WWER implementation.
- The Department of Corrections' prison locations may be a favorable place to implement WWER due to their year-round energy use and waste water generation. Preliminary outreach was not successful within the timeframe of this project.
- The Massachusetts Water Resource Authority (MWRA) conducted a study on WWER for their own headworks buildings, but decided not to implement the technology in their own locations due to unfavorable economic analysis in the feasibility studies. However, MWRA is very interested in the potential of WWER and has identified one of their major pumping stations, the Ward Street Headworks, as an additional potential site. Furthermore, they have reached out to the adjoining Wentworth Institute of Technology to determine if Wentworth would be interested in using WWER in one of their new construction projects.
- The City of Boston is very interested in using WWER as a district energy supply. Contact has been established with the Boston Redevelopment Authority and will be a valuable source of information regarding new constructions and HVAC replacements. In addition, the City of Boston has its own geographic information systems (GIS) mapping program that may be able to overlay planned new construction and HVAC renovations onto waste water access points, such as pumping station wet wells.

With the knowledge of interested sites and locations matching important criteria, the DOER will continue to assess interested sites to determine if a scoping project for the installation of WWER is worth conducting at any of these sites.

*Step 4: Conduct a scoping project on the selected potential site.*

In order to confirm that the selected potential site is a good candidate for WWER, the sites must take part in a scoping project. The scoping project should include a data collection step, which will require that monitoring equipment is installed in the sewer system in the area if this equipment is not already present (Finding 9). This process can take some time to complete because the data that is collected must indicate the flows and temperatures of sewage that the site should expect throughout different times of day and seasons. Within the scoping study, if several sources of waste water are available for WWER, the flows and temperatures of the sewage at these various locations should be mapped. The purpose of this mapping step is to ensure that the site has access to the best sewage source that can be utilized at the location. By the end of the scoping project, the DOER should have enough information to fully evaluate the site in terms of the site selection criteria and proceed with the installation process.

*Step 5: Perform a cost analysis on the selected potential site.*



In order to determine if installation of a WWER system is financially viable at a site, a cost analysis must be performed. A common model used is the simple payback period. The payback period is the point in time when the cost of the installation of the system is balanced out by the amount of savings the system has generated for the user. After the payback period has been met, the system installation and operation nets money for its user. Payback period can be calculated using Equation 4.1.

*Step 6: Design the WWER system for the site.*

The design process should be completed by engineering consultants. The WWER system can be designed to suit the site's needs based on the site's specific parameters. For instance, there are different types and sizes of heat exchangers can be used to extract heat from the sewers. There are also different approaches to separate liquid and solid waste to improve efficiency and decrease the need for maintenance. Each system has its advantages and disadvantages, and once data are collected, an engineer and design team can determine the best fit for the site.

*Step 7: Install the WWER system at the site.*

Installation can vary in cost and timeframe depending on the size of the WWER system, the access to the sewage source, and which components need to be installed. Unexpected costs and barriers to installation may arise and must be dealt with on a case by case basis.

*Step 8: Operate, monitor, maintain, and promote the WWER system.*

Once the pilot WWER system has been installed, it is vital that the system is operated, monitored, and maintained so that the site can be used to promote WWER technology. The promotion of WWER technology will be discussed further in section 5.3.1. The operation and maintenance of the system will require knowledge of the equipment found in typical sewer systems. Regular maintenance should be scheduled, and emergency maintenance should be planned. The monitoring equipment should also be well maintained and should be kept in operation as often as possible. Thorough monitoring and data collection will ensure that the site will be able to provide useful information for anyone seeking to install another WWER system in Massachusetts.

### **5.3 Recommendations for the Promotion of Waste Water Energy Recovery in Massachusetts**

Once a successful pilot site has installed a WWER system, the DOER can proceed to promote the use of this technology throughout the Commonwealth. The pilot site can be used to educate potential users of the technology about WWER and encourage the public to install the technology in other locations. The DOER can also use the pilot site to confirm the viability of the technology and modify regulatory policies to facilitate its implementation and funding. In this section we discuss our recommendations for further actions the DOER should take in order to propagate WWER technology

throughout Massachusetts. We discuss recommendations that relate to education, funding and regulation, and installation of the technology in the future.

### **5.3.1 Recommendations Related to Education**

In this section, we discuss several ways of using the pilot site for educational purposes after it has been successfully installed. The educational programs we discuss have two target audiences. The first is the key stakeholders that could be involved in the installation of WWER technology. These stakeholders include building owners, sewer company representatives, company managers, and municipal directors. Stakeholders should be informed about WWER technology so they are aware of the possibility of installing WWER systems and are willing to implement this technology. The second target audience is the general public. The general public should be made aware of WWER technology so knowledge about the technology can spread more easily than it would if only key stakeholders were informed. Directly informing the general public about WWER also gives the advocates of the technology the ability to dispel any myths about the technology and ensure that the public has access to the most accurate information about WWER.

#### **Recommendation 2:** Open pilot site for educational purposes.

To promote WWER in the Commonwealth, the installed pilot site should be open to the public for viewing and offer tours. Renewable thermal technologies, such as WWER, are not well known by policy makers, the building industry, or the public. At these viewings and tours, the public would be able to see the technology in action, gain knowledge of how WWER works, become aware of the benefits of WWER, and have the opportunity to ask any questions they have and voice their concerns. Having a pilot system installed in Massachusetts would enable Massachusetts policy makers, building owners, and the public to gain the understanding that this technology is locally accessible and is something they could install as well.

As heating and cooling are not tangible, one approach that might be beneficial to the goal of educating the public is the installation of a snow melt system. A town in Colorado is pursuing the idea of using heat recovered from waste water to melt snow on the surfaces as a part of the redevelopment plan. (Williams, 2009) While this specific application was considered for its environmental benefits, applying a snow melt application at or near a WWER pilot site in the Commonwealth would allow for the public to easily see the potential WWER systems have for heating applications.

#### **Recommendation 3:** Facilitate media attention and advertisement for the pilot site.

Once the pilot site is installed and operational, media should be on site covering events to promote WWER. Inviting different media outlets will broaden the viewing platform for this installation and will make WWER better known. Ideally this media coverage will spark communities' interest in learning about WWER systems.

**Recommendation 4:** Supply communities within Massachusetts with information on WWER.

The DOER should provide informational pamphlets on WWER technology to municipalities throughout Massachusetts. Additionally, at events located at the pilot site, informational brochures and pamphlets that we have created (Appendix H) should be distributed. The informational material should include a general overview of the technology, specific benefits, potential costs, and a plan of action to follow if considering implementing WWER. These items should be given to municipal representatives to share with the community at local events such as town meetings. These resources should also include contact information for parties seeking additional information about WWER.

**Recommendation 5:** Hold a webinar for community representatives and other stakeholders within Massachusetts that are interested in WWER.

Holding a webinar is a way to open up communication across the many stakeholders involved in the process of installing WWER. If a municipality is seriously considering WWER, representatives from several different departments and organizations should participate in the webinar. We are providing a slide presentation that should be utilized during the webinar as a general overview of WWER systems and act as a discussion guide between those in attendance. The webinar will be a way of networking between the potential stakeholders, and another opportunity to ask questions and raise concerns among the stakeholders.

**Recommendation 6:** Hold a summit of current owners and vendors of WWER technology.

There are several different organizations around the world that are independently working to implement WWER technology. Holding a summit would allow for open communication between these organizations. This would be an opportunity for the DOER and any other interested parties in Massachusetts to learn from the experience of other organizations that have worked with this technology. It would also be an opportunity for the DOER to share their experience with WWER and further promote its development. Organizations would also be able to collaborate on problems they are facing and how they have been addressed in the past.

### **5.3.2 Recommendations Related to Funding and Regulation**

**Recommendation 7:** Modify regulatory policy to include WWER technology as an eligible technology for funding by the APS.

Massachusetts should consider WWER and other renewable thermal energy sources as a technology eligible for the APS. This would enable a revenue stream from generation of AECs. Inclusion of renewable thermal sources in the APS will require legislative action (Finding 20). The DOER should continue to promote this idea. In many cases current regulatory policy limits funding to systems that replace certain fossil fuel sources. This policy should be modified to accommodate the installation of WWER technology in sites that are replacing propane, electric heating, and fuel oil.

**Recommendation 8:** Evaluate financial models for available for WWER systems.

There are two financial models available for WWER systems: private ownership, and third-party ownership (Finding 14). The DOER should assess each of these models in the context of financing WWER installations. Based on the current knowledge of these financial models, we believe that the private ownership model will be more beneficial for WWER systems servicing individual sites and the third party model will be more beneficial for WWER systems used for district heating. This assessment should be evaluated and expanded on as the DOER conducts further research. As the DOER continues to evaluate these financial models they should also identify a process for determining which of the two models should be used for any given site.

**Recommendation 9:** Facilitate communication between the parties involved in the installation of WWER systems.

A major difficulty in installing WWER technology is connecting the different organizations and stakeholders that are involved with the installation such as local sewer providers, site owners, engineering consultants, and investors, and enabling them to work together (Finding 21). As a state agency, the DOER is in a position to facilitate collaboration between the parties involved in the installation process. If a site representative approaches the DOER with the intention of installing a WWER system, the DOER should make efforts to connect that representative with the agencies they will need to contact. The DOER should also ensure that all of the stakeholders and agencies involved in the installation process are communicating as early in the process as possible.

### **5.3.3 Recommendations Related to Future Site Installation**

**Recommendation 10:** Encourage sites to initiate the installation of their own WWER systems.

After the pilot site has been operating, the data collected from the pilot site can be used to promote WWER to other sites. By showing other sites that a pilot WWER system preforms successfully, the DOER can encourage other sites to follow a similar plan of action to install a system of their own. At this point, the DOER is approaching sites to participate in a pilot program. Once this technology is more established in the Commonwealth, sites should be expected to initiate the installation process on their own and seek out support from the DOER. The DOER should then be prepared to provide this support by directing the site as they apply for funding and by facilitating communication between the parties involved in the installation process, as discussed in Recommendations 15 and 16.

**Recommendation 11:** Provide steps for interested sites to follow in order to install WWER systems.

To install WWER systems in the future at locations other than the DOER's pilot site, information should be available regarding the implementation process. The process of implementation for future locations mimics that of the pilot site implementation. The only difference between the two is the steps prior to site evaluation. In a pilot site implementation, the DOER researches and approaches sites that appear to fit some major criteria through basic evaluation with the primary

goal of the site being evaluation and education. In the future, the hope is that sites, due to the information and education available as a result of the pilot site, will choose WWER without being approached by the DOER. Please refer to Figure 5.2 in Recommendation 9 for the step by step process of implementation. Just as in a pilot site, future sites should conduct site evaluations using the criteria, involve key stakeholders from the start of the project, conduct a scoping project, conduct cost analysis, design and system, and after installation, operate, monitor, maintain, and promote the WWER system.

## **5.4 Conclusion**

Through the completion of this project, we met our objectives of creating a list of criteria that can be used to evaluate potential WWER installation sites, suggesting a process by which a pilot WWER system can be installed in Massachusetts, and identifying strategies for the future implementation of WWER. By completing these objectives, we have added to the available knowledge of WWER. We have also enabled the DOER to proceed with the completion of their goal of increasing the availability of WWER technology throughout the Commonwealth of Massachusetts. As the DOER uses the products of this project to install and promote WWER technology throughout Massachusetts, the Commonwealth will be gaining an additional source of alternative energy. The resulting increase in the use of WWER technology and alternative and renewable energy in Massachusetts as a whole will further contribute to the progress being made in the Commonwealth toward a sustainable future.

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## Appendix A: Terms and Definitions

**alternative-** not derived from fossil fuels but cannot be considered renewable Example: biodiesel, combined heat and power, waste-to-energy

**annulus-** the outer pipe in a concentric tube heat exchanger

**application site-** location where the WWER derived energy is used

**Coefficient of performance (COP)-** in either a heat pump or complete WWER system, the ratio of heat energy yielded to the electrical energy consumed

**collection site-** location where the WWER technology is installed and accesses sewer energy

**Successful site-** a site whose installation of WWER technology has proven to be both cost effective and energy efficient, has reduced the site's greenhouse gas emissions, and has lasted or is expected to last for the technology's estimated lifespan with reasonable ease of maintenance

**on-site-** at the site of the treatment plant

**off-site-** WWER applications that use the energy at some other location, usually within close proximity to the sewage source

**renewable-** derived from a source that is constantly and naturally replenished Example: solar, wind, hydroelectric

**temperature lift-** the difference between fluid temperatures before and after heat pump circulation

**WWER system-** the installed WWER unit

**WWER technology-** the general technology involved in recovering energy from waste water

## Appendix B: Interview Guides

### Appendix B.1: Vendor Interview

#### *Initial Contact*

- Introduction
  - MA DOER and WPI
  - Looking for information on WWER
  - Your company/organization came up in our search
  - Are you interested in setting up an interview with us in the coming week?

#### Example

“Hi My name is----- and I’m calling from the Mass. Dept of Energy Resources. I’m also a student at Worcester Polytechnic Institute in the Commonwealth of Massachusetts. We are currently working on some research to aid in further implementation of Waste Water Energy Recovery technologies in the Commonwealth and your technology came up in our inquiries. Would you be interested in scheduling a time to talk with us about your site’s application of Waste Water Energy Recovery?”

#### *Opening of Interview*

- Introduce yourself and teammates
- Thank them for their time
- Talk about project specifics
- Review confidentiality

#### Example:

“Once again, my name is ---- and I just wanted to first off take some time to thank you for agreeing to talk with us. As you know, WWER is an up and coming technology and we want to hear from the people who experience and develop it first hand, that’s you!

Just to give you a little background, I am working on a team with two other WPI students in conjunction with the MA DOER. Our goal is to compile information regarding this technology as well as make some suggestions for piloting future sites.

**\*In regards to confidentiality, we agree to keep all your answers confidential, meaning we won’t report that your name or site is associated with your responses unless you state otherwise.\***

### Background Information

1. How long has your company been involved in the development of waste water energy recovery technologies?
2. What locations have you implemented this technology in?
3. What inspired your company’s use of WWER technologies?
4. What is your position in relation to (Vendor name)? Who do you usually interact with?

## Resources

1. What were some of the studies, previous implementations, and other technologies that influenced and aided in the research and development?
  - a. Resources
  - b. Do you have any reports or studies connected with your developed system or a site that has benefited from your technology that you are willing to share with us? (eg testing data before final product was released to the market)
  - c. Can you send us any brochures or pamphlets that you distribute to communities to inform them on the technology?

## Technology

1. How does your system work?
  - a. Structural components - order of components in the system
  - b. Min/max flow rate - needed & produced
  - c. Min/max temperature - needed & produced
  - d. Space heating, space cooling, water heating, water cooling
2. What is involved in the installation process?
  - a. Machinery, manpower etc.
  - b. What sewer features do you need access to in order to install your system?
  - c. Pipes, wetwell, lift station, space, through manhole or other access point?
  - d. Does your system require modifications to existing HVAC systems? If yes, what type of systems require modification?
  - e. Are there size constraints with installing this technology?
  - f. Can your system be installed as both an upgrade and a retrofit?
  - g. Does the installation process disrupt the workplace?
  - h. Does the installation of the system require a large amount of energy?
3. Do you modify your system for different applications?
  - a. What types of modifications?
  - b. Do building size and type affect which technology is required?
  - c. Does climate affect your system's ability to function properly?
4. Do the systems require monitoring or maintenance?
  - a. What does that maintenance entail?
  - b. How frequently is maintenance performed?
  - c. Who is responsible for maintaining the system once it has been installed?
  - d. What is the approximate cost of maintenance on a yearly basis?
5. Expected lifetime of measure, warranty length

## Site Selection

1. Where have you implemented this technology?
2. How do you choose a site to implement this technology in?
  - a. For example: What is the first thing you consider when assessing a site and why?
3. What were attributes that made potential sites attractive for installation?
  - a. Physical, social, financial
  - b. Why were those attributes important?

4. Does the age of the building or sewage infrastructure at the site affect your ability to install your system?
  - a. Is it easier to replace or retrofit?
5. What barriers have been present at installation sites that have made it difficult to implement this technology?
6. Does your location limit the sites you are willing to install this technology in?
  - a. International vs. local companies
7. Is your company exploring the Northeast Market?

## **Energy**

1. How much energy does the technology use while operating?
  - a. What fuel source does this require?
  - b. Are there automated settings that can help reduce operating costs and energy usage? (VFDs = variable flow drives?)
2. How much energy does a typical system provide?
  - a. Any measurements of energy performance, coefficient of performance?
  - b. What are the energy savings of your system compared to a standard gas/oil/electric heating system (in MWh or Btu per year)
  - c. What are the characteristics of the energy load in a building that is a good fit for your technology? (all year constant use, need for lots of space heating, high hot water need, different zones throughout the building with different temperature needs)

## **Financial**

1. How much does a system for a typical site cost?
  - a. What is the cost of installation?
  - b. Does the cost of installation differ for retrofitted systems and systems that were replaced?
  - c. What is the cost of maintenance?
2. How much money is your system expected to save your customers?
  - a. Payback period - accounting for installation & operating costs
  - b. Monthly or annual percent savings

## **Regulatory**

1. Have you or your customers faced any regulatory issues in installing your systems?
2. When installing this technology, what regulatory steps do you have to go through?
  - a. What permits (if any) need to be obtained prior to installation?
  - b. What organizations will need to be consulted in order to meet all of these regulations?
3. Are your customers eligible for tax rebates or grants?
4. How long does the process take?

## **Closing:**

1. What sets your company apart from other WWER technology providers?

## Appendix B.2: Previous Installations

### *Initial Contact*

- introduction
  - MA DOER and WPI
  - Looking for information on WWER
  - Your site came up in our search
  - Are you interested in setting up an interview with us in the coming week?

### Example”

“Hi My name is----- and I’m calling from the Mass.Dept of Energy Resources. I’m also a student at Worcester Polytechnic Institute in the Commonwealth of Massachusetts. We are currently working on some research to aid in further implementation of Waste Water Energy Recovery technologies in the Commonwealth and your site came up in our inquiries. Would you be interested in scheduling a time to talk with us about your site’s application of Waste Water Energy Recovery?”

### At start of the of the interview-

- Introduce yourself and teammates
- Thank them for their time
- Talk about project specifics
- Review confidentiality

### Example:

“Once again, my name is ---- and I just wanted to first off take some time to thank you for agreeing to talk with us. As you know, WWER is an up and coming technology and we want to hear from the people who experience it first hand, that’s you!

Just to give you a little background, I am working on a team with two other WPI students in conjunction with the MA DOER. Our goal is to compile information regarding this technology as well as make some suggestions for piloting future sites.

In regards to confidentiality, we agree to keep all your answers confidential, meaning we won’t report that your name or site is associated with your responses unless you state otherwise.”

## Background

1. Describe the WWER project that you are involved in.
  - a. What was your involvement is the project?
    - i. Job position?
  - b. Did your project receive any press coverage?
  - c. How did you become aware of waste water energy recovery (WWER)?
  - d. What types of systems did you consider for your location?
  - e. What system did you choose and why?

Do you use any other renewable or alternative energy technologies?

Do you have a report or study connected to your location? (Can keep it confidential if necessary)

## Site Specifications

1. Can you tell me about the implementation site?
  - a. Can you tell me specifics about the building and your WWER system?
    - i. What type of building did you install WWER technology in?
    - ii. What size is the building?
    - iii. Does the building have a high population?
    - iv. What type of heating system did you use before installing your WWER system?
      1. What fuel did your old heating system use?
    - v. Did you replace or upgrade your system?
      1. Was your old heating system due for replacement?
    - vi. Does your WWER system meet your building's heating needs entirely or are you using it to supplement an additional heating system?
      1. What other heating systems are you currently using?
        - a. What types of fuel do your additional heating systems use?
    - vii. Are you using your WWER system for space heating, space cooling, water heating, or water cooling?
    - viii. Is the WWER system in or close to the building?
    - ix. Is the WWER system in or close to the sewer?
      - x. Did finding a space to put the system cause any problems for you?
      - xi. Did finding access to the sewer pipes cause any problems for you?
    - xii. What flow rate of waste water does your system have access to?
    - xiii. What is the average temperature of the waste water your system has access to?
    - xiv. What temperature does the incoming water need to be raised to for your application?
    - xv. Does your location's climate affect your system's ability to function? (what is the climate like)
    - xvi. Do you find that your system functions more or less effectively depending on the season?
  - b. Which qualities did you find have the most impact on the success of your WWER project?
    - i. Which is the most important to consider?
    - ii. Are there others that you looked at that we missed?
  - c. Are there any qualities about your site that you believe caused a difficulty or setback for you?
  - d. Did you monitor your energy usage and the temperature and flow rates of the available waste water before installing your system?
    - i. If yes: Do you believe monitoring these before installing your system contributed to your site's success?
    - ii. If no: Do you believe monitoring these before installing your system would have been worthwhile?

## **Energy**

1. How much energy did you use to heat your site before your WWER system was installed?
2. How much energy does your WWER system use to operate?
  - a. What fuel is this energy produced from?
3. How much energy are you using to heat the building in addition to the energy required to operate your WWER system?
  - a. What fuel is this energy produced from?
4. What data do you have available on your location's success and energy savings?

## **Financial**

1. Cost
  - a. How much money did your system cost to install?
    - i. How did this compare to other technologies you considered?
  - b. How much money does your system cost to maintain?
  - c. Were able to utilize any grants or tax rebates to finance the project?
2. Savings
  - a. How much did you pay for your heating needs before you installed your WWER system? After?
    - i. What is the cost of your energy?
  - b. How much money do you expect to save by using this system?
    - i. Annual cost savings?
    - ii. Lifetime cost savings?
  - c. What was the payback period for this application?
  - d. How long do you expect this system to last before you will have to replace it?

## **Social**

1. Did you inform the public that you would be installing this system?
  - a. How?
2. What was the reaction of the public?
  - a. How did the users of the building react?
  - b. How do you know?
    - i. Did you conduct surveys?
3. Did the installation cause any interruptions or inconveniences in the workplace?

## **Regulatory**

1. What was the regulatory process your site underwent in order to implement this technology?
  - a. How did you receive permission to install WWER technology?
  - b. Who did you need to receive permission from?
  - c. Did you encounter any problems during the regulatory process?
    - i. How did you solve these problems?

## **Additional Challenges**

2. What other challenges or barriers did you face in implementing this technology?

3. How did you overcome them?
4. Have you faced any difficulties operating or maintaining the system?
5. Did the difficulty of operation and maintenance meet your initial expectations?
6. Do you have any suggestions for a site looking to implement this technology based on your experience?

### **Future Contact Information**

1. What is the best way to contact you in the future if we have any more questions?
2. Would you like to view any of your quotations we plan on using in our report?
3. Would you be interested in a copy of the report once complete?



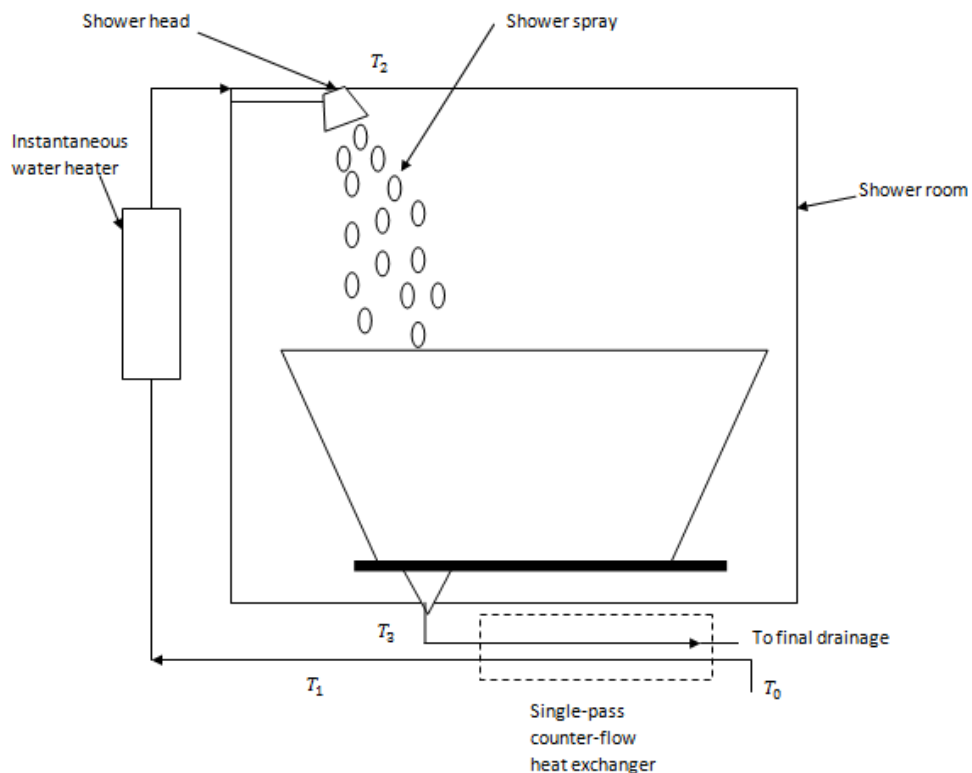
## **Appendix C: Interview Summaries [Confidential]**

## **Appendix D: Interview Notes [Confidential]**

## Appendix E: Hong Kong Case Study

The Department of Building Services Engineering at The Hong Kong Polytechnic University in Hong Kong China completed a study on recovering heat from shower water in high-rise residential buildings of Hong Kong. It was found that residential buildings consume 17% of the total energy of Hong Kong. Consumption in residences showed that 20% of the energy used was for the production of hot water of which a large portion was used for personal hygiene such as bathing or showering. This study investigated potential heat recovery using “Monte-Carlo simulations” (Wong, 2010).

This technology utilized a simple, single-pass counter-flow heat exchanger that was horizontally installed beneath the shower drain. It was assumed that no heat was lost from the short pipe length collecting the hot water from the shower. The figure below illustrates the arrangement in a typical bathroom (Wong, 2010).



$T_0$  = cold water temperature

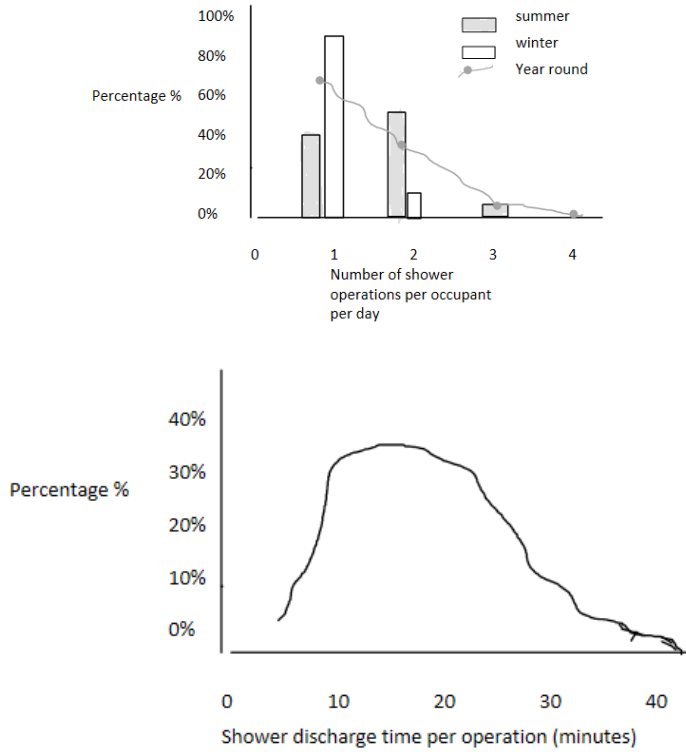
$T_1$  = temperature leaving heat exchanger

$T_2$  = shower head water temperature

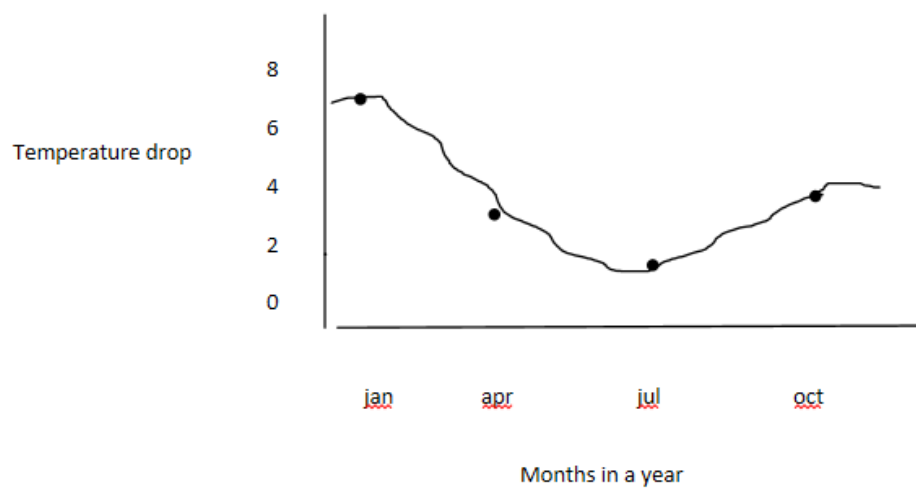
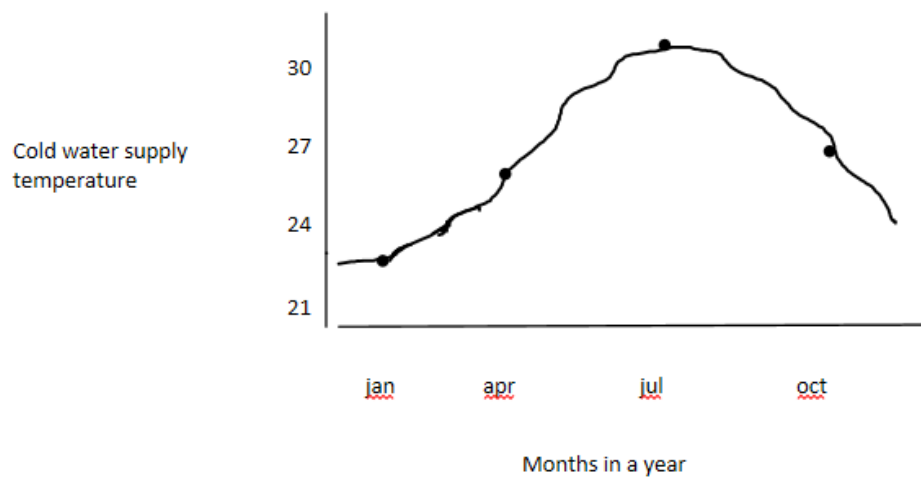
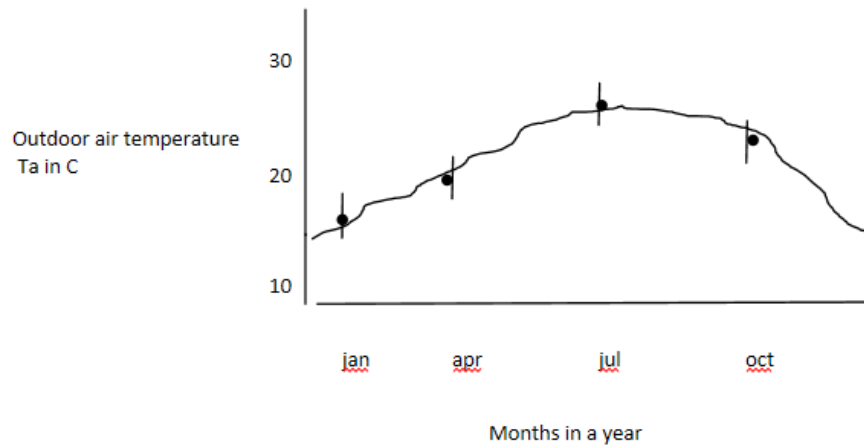
$T_3 = \text{drain water temperature}$

The following equation was used to calculate power consumptions for heating water with and without the heat exchanger,  $\dot{Q}_1$  (kW) and  $\dot{Q}_0$  (kW) respectively. Note that  $T$  is in ( $^{\circ}\text{C}$ ) and  $c_p$  ( $\text{kJ kg}^{-1} \text{ }^{\circ}\text{C}^{-1}$ ) is the specific heat capacity and  $m_c$  ( $\text{kg s}^{-1}$ ) is the mass flow rate of cold water supply entering the heat exchanger (Wong, 2010). 
$$\begin{cases} \dot{Q}_0 = m_c c_p (T_2 - T_0) \\ \dot{Q}_1 = m_c c_p (T_2 - T_1) \end{cases}$$

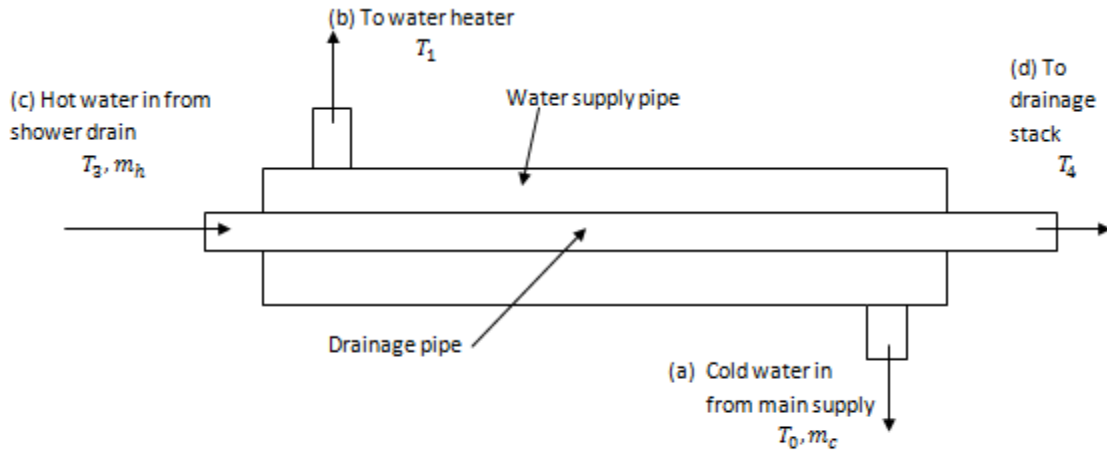
The amount of heat produced was related to shower usage patterns. To gather information regarding shower usage, a total of 1300 households were picked at random from 14 typical high-rise residential buildings among five housing complexes in Hong Kong. Of the population of 113,000 that resided in the included residential areas chosen, 597 responded through face-to-face interviews. Information of shower usage patterns were gathered for the time period of the day prior, weekdays, and holidays. Time of year was also considered. For each installed shower appliance, the type, physical size, brand name, usage frequency and water flow rate were recorded. The results were compiled into the following two graphs (Wong, 2010).



The researchers also took temperature measurements by taking showers in a high-rise residential apartment with two typical bathrooms for 4 weeks in a year, i.e. 1 week each in January, April, July, and October of a year. Although the sample cases were assumed typical, future measurements with statistical analysis would improve confidence levels. Using thermocouples, temperatures at the main water supply, shower heads and shower drains were measured and logged in 5 second intervals. At the time outside temperatures ranged from 13 °C to 28 °C by using  $T_0 = 10.4(T_a^{.29})$  ;  $13 \leq T_a \leq 28$  and  $\Delta T_{2,3} = T_2 - T_3 = 3.6(10^{-10}) * T_2^{6.6673} * T_2^{-.530}$ , it was found that the temperature observed at the shower head  $T_2$  (°C) stayed relatively constant with an average of 40.9 °C (SD = 1.0 °C), but It dropped down to  $T_3$  (°C) at the shower drain in all observations. The results were compiled into the following graphs (Wong, 2010).



An experiment was up to measure the heat exchanger effectiveness. Pipes were measured by K-type thermocouples at locations (a), (b), (c) and (d), at gradients 1/500, 1/250, 1/200, 1/125, 1/67, 1/40, and under testing conditions of hot water temperatures from 38 °C to 40 °C, and cold water temperatures from 14 °C to 16 °C. The experiment was set up as following (Wong, 2010).



**Experimental Setup – Schematic cross-section of the heat exchanger**

The following equations were used to numerically determine heat exchanger effectiveness and the findings are expressed in the diagram below (Wong, 2010).

$$\varepsilon = \frac{\dot{Q}}{\dot{C}_{min}(T_3 - T_0)}$$

$$\dot{Q} = \dot{C}_{min}(T_1 - T_0)$$

$$\dot{C}_{min} = \min(\dot{C}_c, \dot{C}_h); \begin{cases} \dot{C}_c = m_c c_p \\ \dot{C}_h = m_h c_p \end{cases}$$

Potential energy savings were modeled using the expression,  $S = \frac{\sum E_{0j} - \sum E_{1j}}{\sum 0_j}$

where the annual energy savings is  $S\%$ ,  $E_0$  ( $\text{kWh year}^{-1}$ ) is the annual energy consumption without the heat exchanger, and  $E_1$  ( $\text{kWh year}^{-1}$ ) is the annual energy consumption with the heat exchanger installed. If considering this sample building, the total annual thermal energy savings expected was  $104 \text{ MWh year}^{-1}$  ( $\text{SD} = 21 \text{ MWh year}^{-1}$ ) to  $406 \text{ MWh year}^{-1}$  ( $\text{SD} = 84 \text{ MWh year}^{-1}$ ), wherein the expected annual thermal energy consumption for hot water showers was  $60.7 \text{ kWh m}^{-2} \text{ year}^{-1}$  ( $\text{SD} = 13.3 \text{ kWh m}^{-2} \text{ year}^{-1}$ ) (Wong, 2010).

Conclusions made by this study are as following. It was noted that assumptions made in the system arrangements, simulations and experimental errors would pose uncertainties to the estimates. The results indicated that annual energy savings of 4–15% from shower water heat could be achieved through a 1.5 m long single-pass counter-flow heat exchanger for a drainage pipe of diameter 50 mm. Waste heat recovery from shower drains in high-rise residential buildings in hot and humid climates is challenging. Apart from space limitations for the installations, good designs of heat exchanger with justified payback period are essential (Wong, 2010).

## Appendix F: Criteria Development

Criteria (finding #)	Source(s)
3 new construction or complete system replacement; not addition to system	("There's money in sewers", 2013), (H. Russell, personal communication, September 12, 2013), (P. Nelson, personal communication, September 19, 2013), (K. _____, personal communication, September 23, 2013), (Vandenburgh, 2011)
1 application near sewage source	("There's money in sewers", 2013), (P. Nelson, personal communication, September 19, 2013), (K. _____, personal communication, September 23, 2013), (Funamizu, 2001), (Vandenburgh, 2011)-5.mi, *Mayor Nutter case"
2 ideal sewage source: lift station or wet well	(G. Sauter, personal communication, September 3, 2013), (H. Russell, personal communication, September 12, 2013), (Vandenburgh, 2011)-not explicitly stated but site used wetwell, (Fay, Spofford & Thorndike, 2013b)
4 high flow rate of sewage available (appropriate flow rate for chosen technology)	(Chen, 2011)-500-600 gpm/100,000 sq. ft., (P. Nelson, personal communication, September 19, 2013), (Vandenburgh, 2011)
10 most cost effective if replacing high cost fuel like electricity	(K. _____, personal communication, September 23, 2013)
short payback period: ideally 10 years or less (HUBER)	(H. Russell, personal communication, September 12, 2013), (Authority, M. W. R., 2013)
8 Large demand for heating or cooling year-round *(better if cooling year-round ("There's money in sewers", 2013))*	("There's money in sewers", 2013), (Vandenburgh, 2011), (Authority, M. W. R., 2013)
11 availability of government or utility funding for construction	(Fay, Spofford, & Thorndike, 2013)
5 wastewater temperatures in the required range for effective heating/cooling	(Fay, Spofford, & Thorndike, 2013)
relatively low electricity unit costs supplemental to fuel source (i.e. oil, natural gas, electricity)	(Fay, Spofford, & Thorndike, 2013), (McCormick, Carkrabari, & Liner, 2012), (Fay, Spofford & Thorndike, 2013b)
adequate heat extraction capacity (COP)	(McCormick, Carkrabari, & Liner, 2012)
available data / data collection	("There's money in sewers", 2013)
	(P. Nelson, personal communication, September 19, 2013)



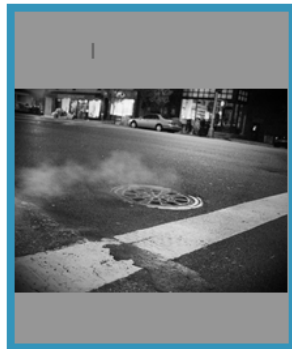
## Appendix G: Literature Overview

Name of Report	Aquisition	General Content
Heating and Cooling in the APS	DOER-Bram Claeys	MASS specifics regarding renewables
Massachusetts Heating and Cooling Opportunities and Impact study "Markets"	DOER-Bram Claeys	has a relevant set up on analyzing technology
American Planning Association POLICY GUIDE ON PLANNING & CLIMATE CHANGE	Online search, APA	basic information on climate change and future planning guide
Feasibility Study for Wastewater Heat Recovery at Chelsea Creek Headworks	MWRA	Keywords: LCCA., Wastewater, Heatpumps. (general Content but also includes LCCA Appendices)
Executive Summary of Feasibility Study for Wastewater Heat Recovery at Chelsea Creek Headworks	MWRA	summary of the article above ^
Cost Estimate Condensing Boilers	MWRA	HVAC system costs information
MWRA Investigation of Waste Water Heat Pump Applications	MWRA	Keywords: Heat Pumps, Criteria, Wastewater, Cost, Feasibility, Applications, Contact info
The WEF Energy Roadmap	James Newton	Keywords: MATRIX, energy, CHP
Mayor Nutter Cuts Ribbon on Wastewater Geothermal Heating Project	DOER- Aimee Powelka	New Philadelphia Site
There's Money in Sewers	HUBER- Henry Russell	Keywords: Attributes, Criteria
Cost Estimate Heat Pump	MWRA	HVAC system costs information
Wastewater Heat Recovery Technical Memorandum (Final Heat Pump Report)	MWRA	
Combined Geothermal and Wastewater Heat Recovery Feasibility Study	MWRA	Evaluation of technology, comparison, geothermal, flow rates, energy demands
Thermal Heat from Sewage research	Philly - Bill Toffey	compilation of Philly's resources
Seal Support Systems	DOER- Aimee Powelka	example of life cycle analysis
Wastewater Heat Extraction for Commercial HVAC Applications: A U.S. Pilot Project	Philly - Bill Toffey	equations and figures, gpm/sq ft requirement, criteria
Recovery of Effluent Heat for Beneficial Use in Biosolids Stabilization	Philly - Bill Toffey	interesting methodology section
US Patent for Heat Pump System	Philly - Bill Toffey	1984 patent, technology specifics
Reuse of heat energy in wastewater: implementation examples in Japan	Philly - Bill Toffey	equations and figures, criteria
Using Wastewater Energy to Heat an Olympic Village for the 2010 Winter Olympics and Beyond	Philly - Bill Toffey	Vancouver case study and site specs
Heat Extraction from Plant Effluent (Aimee- Page 74)	Philly - Bill Toffey	specs on different heat pumps and applications
Towards Net Zero- Reducing Community Energy and Water Consumption by 50%	Philly - Bill Toffey	relevant info regarding demand and consumption
Wastewater Effluent is Hot - Capturing Effluent Heat for Swimming Pools and Snowmelt Systems	Philly - Bill Toffey	criteria, shows a set up of a paper

Name of Report	Aquisition	General Content
Colorado Community Benefits From Installing Waste Heat Recovery System	Philly - Bill Toffey	shows actual data and diagrams
Water & Wastewater Energy Management Best Practices Handbook	Philly - Bill Toffey	good table of contents and overview
Waste Water Treatment Plant Designs and Operations	DOER - research from Aimee P	relevant info on schools looking to install on site WWTP etc - one of them is Pembroke !
HUBER RoWin Heat Exchanger	research by Erica	Specs on Heat Exchanger
HUBER Wastewater Energy Recovery Brochure	research by Erica	Wastewater, flow rate, temperature, efficient, cost-effectiveness
ROTAMAT RoK4 Pumping Station Screens	research by Erica	flow rate
Additional HUBER research	research by Erica	temperature
MWRA contract 7274A	MWRA - Kristen Patneaude	cost-effectiveness
CY11 ww data	MWRA - Kristen Patneaude	
Deer Island Plant monitoring system set up	MWRA - Kristen Patneaude	
Deer Island Info	MWRA - Kristen Patneaude	
Wastewater Treatment Article	online search-Erica Parker	wet well and lift station information
About HUBER	online search-Erica Parker	general info about huber
Energy From Wastewater	online search-Erica Parker	HUBER's solution to WWER
Sewer Heat Recovery Provides Low-Cost Recycled Energy	DOER - John Ballam	
Heat Exchangers in Municipal Wastewater Treatment Plants	DOER - John Ballam	
Effectiveness Concept for Heat Exchangers	DOER - John Ballam	
HUBER ThermWin Heat Exchanger	HUBER_ Chris Hubbard email	Keywords: TABLE - Cost, WW Flow Rates, Energy Transfer
REGULATIONS GOVERNING THE USE OF SANITARY AND COMBINED SEWERS AND STORM DRAINS OF THE BOSTON WATER AND SEWER COMMISSION	<a href="http://bwsc.org">bwsc.org</a>	

# Appendix H: WWER Flyer

Side 1

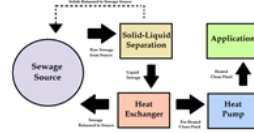


"A study shows that if 5% of heat were removed from waste water flowing through the sewer pipes beneath the streets of NY over the course of 1 year, \$90,000,000 worth of energy could be recovered"



## Waste Water Energy Recovery

### What is WWER?



WWER is the process by which heat energy is transferred from or to waste water for heating or cooling applications respectively.

WWER technology works by adapting the technology that is already used by sewer systems for use in energy recovery applications.

### How does it work?

To start, the sewage is diverted from its source to a solid liquid separation unit. The sewage is then processed by the solid liquid separation unit and the solid sewage is returned to the sewage source. The liquid sewage is then pumped through a heat exchanger. Here, the heat from the liquid sewage is transferred to a clean working fluid. The heat transfer process occurs without the fluids ever coming into contact. Next, the liquid sewage is returned to the sewage source and the clean working fluid is pumped to a heat pump. Here, the temperature of the clean working fluid is elevated to the desired outlet temperature so it can be used in the heating application. This process can also be used in cooling applications by transferring heat to the liquid sewage instead.

### Short blurb about DOER

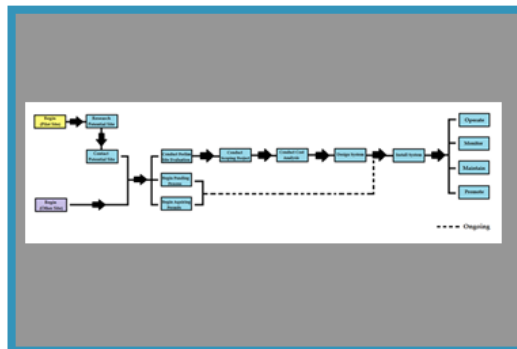
Massachusetts Department of Energy Resources  
Aimee Powellka  
Green Communities Division  
100 Cambridge Street  
Suite  
Boston, MA 02142  
P: 617-624-6666  
E: email@address.com  
www.webaddress.com

Side 2

## Interested in using WWER?

### Steps to take:

- Step 1: Research potential sites.
- Step 2: Contact potential sites.
- Step 3: Use criteria to evaluate potential sites.
- Step 4: Conduct a scoping project on the selected potential site.
- Step 5: Perform a cost analysis on the selected potential site.
- Step 6: Design the WWER system for the site.
- Step 7: Install the WWER system at the site.
- Step 8: Operate, monitor, maintain, and promote the WWER system.



Step-by-step process to implement a WWER system

### For more information:

Our paper online, DOER contacts

Criteria	Ideal Case
Access to sewage source	Sewage source close to application and surface
Status of existing WWC system	New construction or total system replacement
Heating and cooling load	Constant year round demand
Sewage flow rate	High when compared to energy need
Sewage access point	Wet well or lift station
External funding	Grants or tax rebates available
Energy source reduced or supplemented	High cost energy source such as electric heating
Electricity cost	Low cost per kWh
Sewage temperature	Consistently in operating range of heat exchanger
Monitoring System at or Near the Site	Sewage data available prior to installation

Criteria used to implement a WWER system